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# REPORT OF APOLLO 204 REVIEW BOARD

TO  
THE ADMINISTRATOR  
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

(NASA-TM-108667) REPORT OF APOLLO  
204 REVIEW BOARD (NASA) 149 p  
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### **APOLLO SPACECRAFT**

The spacecraft (S/C) consists of a launch escape system (LES) assembly, command module (C/M), service module (S/M), and the spacecraft/lunar module adapter (SLA). The LES assembly provides the means for rapidly separating the C/M from the S/M during pad or suborbital aborts. The C/M forms the spacecraft control center, contains necessary automatic and manual equipment to control and monitor the spacecraft systems, and contains the required equipment for safety and comfort of the crew. The S/M is a cylindrical structure located between the C/M and the SLA. It contains the propulsion systems for attitude and velocity change maneuvers. Most of the consumables used in the mission are stored in the S/M. The SLA is a truncated cone which connects the S/M to the launch vehicle. It also provides the space wherein the lunar module (L/M) is carried on lunar missions.

### **TEST IN PROGRESS AT TIME OF ACCIDENT**

Spacecraft 012 was undergoing a "Plugs Out Integrated Test" at the time of the accident on January 27, 1967. Operational Checkout Procedure, designated OCP FO-K-0021-1 applied to this test. Within this report this procedure is often referred to as OCP-0021.

### **TESTS AND ANALYSES**

Results of tests and analyses not complete at the time of publication of this report will be contained in Appendix G, Addenda and Corrigenda.

### **CONVERSION OF TIME**

Throughout this report, time is stated in Greenwich Mean Time (GMT). To convert GMT to Eastern Standard Time (EST), subtract 17 hours. For example, 23:31 GMT converted is 6:31 p.m. EST.



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

April 5, 1967

IN REPLY REFER TO

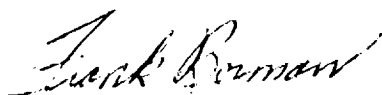
The Honorable James E. Webb  
Administrator  
National Aeronautics and Space Administration  
Washington, D. C. 20546

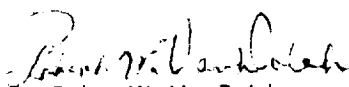
Dear Mr. Webb:

Pursuant to your directive as implemented by the memorandum of February 3, 1967, signed by the Deputy Administrator, Dr. Robert C. Seamans, Jr., the Apollo 204 Review Board herewith transmits its final, formal report, each member concurring in each of the findings, determinations, and recommendations.

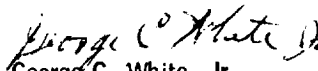
Sincerely,

  
Dr. Floyd L. Thompson  
Chairman

  
Frank Borman, Col., USAF

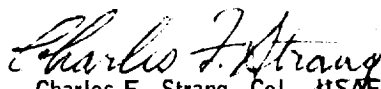
  
Dr. Robert W. Van Dolah

  
Dr. Maxime A. Faget

  
George C. White, Jr.

  
E. Barton Geer

  
John J. Williams

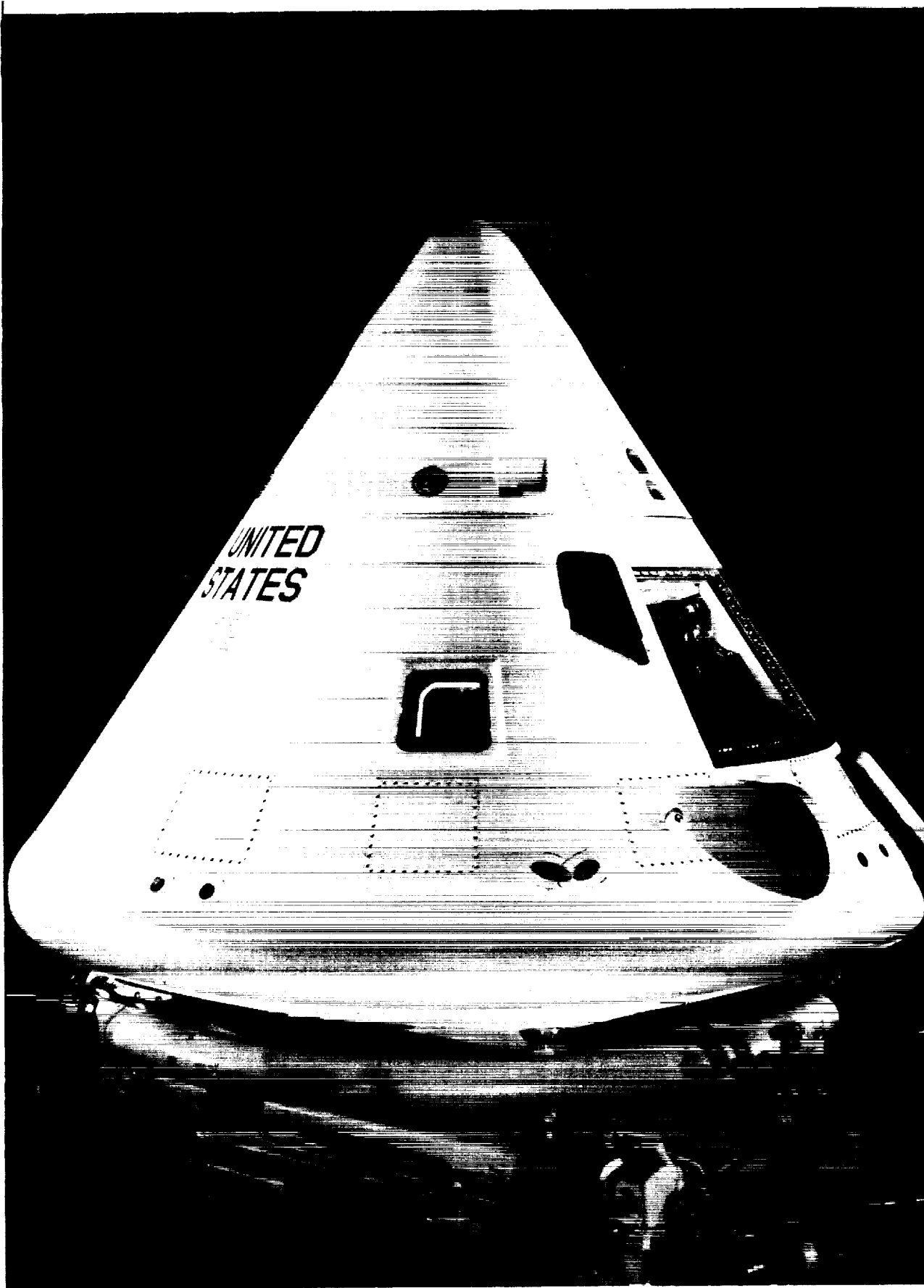
  
Charles F. Strang, Col., USAF

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**REPORT  
OF  
APOLLO 204 REVIEW BOARD**

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## **PREFACE**

The Nation's space program requires that man and machine achieve the highest capability to pursue the exploration of space. Three gallant men lost their lives in line of duty during the development of that capability.

The Apollo 204 Review Board was charged with the responsibility of reviewing the circumstances surrounding the accident, reporting its findings relating to the cause of the accident, and formulating recommendations so that inherent hazards are reduced to a minimum.

Throughout its proceedings, the Board recognized the need for an impartial and totally objective review in order to arrive at its findings. The Board believes that this was accomplished.

The Board is very concerned that its description of the defects in the Apollo Program that led to the condition existing at the time of the Apollo 204 accident will be interpreted as an indictment of the entire manned space flight program and a castigation of the many people associated with that program. Nothing is further from the Board's intent. The function of the Board has been to search for error in the largest and most complex research and development program ever undertaken. This report, rather than presenting a total picture of that program, is concerned with the deficiencies uncovered.

The Board has been greatly impressed by the integrity, candor and dedication of those people upon whom the Board relied in conducting this investigation. All have felt a personal loss in this accident, and all are determined that a comparable tragedy shall not occur.

This report represents the dedicated effort of many hundreds of individuals in government, industry and educational institutions. In addition, useful advice was received from many private individuals in this country and abroad. The Board acknowledges with appreciation these contributions.

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# APOLLO 204 REVIEW BOARD

## FINAL REPORT

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**PART I**

**AUTHORITY**

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## NARRATIVE OF BOARD HISTORY

By authority of the Administrator, National Aeronautics and Space Administration, the Apollo 204 Review Board was established January 27, 1967. This action was initiated through oral instructions issued by the Deputy Administrator, followed by written confirmation February 3, 1967, setting forth, in detail, the broad powers and responsibilities of the Board.

The Review Board convened at Kennedy Space Center (KSC), Florida, on January 28, 1967, under the Chairmanship of Dr. Floyd L. Thompson, Director of the Langley Research Center. The sessions and organized activities of the Board continued at KSC until the Board submitted its Report.

During this period an intensive review was carried out in accordance with the responsibilities placed on the Board by the Administrator. A principal element of this Review was the creation of 21 Task Panels manned by experts in their respective fields. The report of these Task Panels provided the main source of information from which the Board has formulated its findings and recommendations. Periodic interim reports were provided the Administrator.

With completion of this report, the Board has been recessed subject to being reconvened at the call of the Chairman.

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NMI 8621.1 \_\_\_\_\_

April 14, 1966 \_\_\_\_\_

*Effective date*

# Management Instruction

**SUBJECT:** MISSION FAILURE INVESTIGATION POLICY AND PROCEDURES

1. PURPOSE

This Instruction establishes the policy and procedures for investigating and documenting the causes of all major mission failures which occur in the conduct of NASA space and aeronautical activities.

2. APPLICABILITY

This Instruction is applicable to NASA Headquarters and field installations.

3. DEFINITION

For the purpose of this Instruction, the following term shall apply:

In general, a failure is defined as not achieving a major mission objective.

4. POLICY

- a. It is NASA policy to investigate and document the causes of all major mission failures which occur in the conduct of its space and aeronautical activities and to take appropriate corrective actions as a result of the findings and recommendations.
- b. The Deputy Administrator may conduct independent investigations of major failures in addition to those investigations required of the Officials-in-Charge of Headquarters Program Offices as set forth in paragraph 5a.

5. PROCEDURES

- a. Officials-in-Charge of Headquarters Program Offices are responsible, within their assigned areas, for:
  - (1) Informing promptly the Deputy Administrator of each major failure and apprising him of the nature of the failure, status of investigations, and corrective or other actions which are or will be taken.

April 14, 1966

- (2) Determining the causes or probable causes of all failures, taking corrective or other actions, and submitting written reports of such determinations and actions to the Deputy Administrator.
- b. When the Deputy Administrator decides to conduct an independent investigation, he will:
  - (1) Establish a (name of project) Review Board, comprised of appropriate NASA officials;
  - (2) Define the specific responsibilities of each Board, encompassing such tasks as:
    - (a) Reviewing the findings, determinations and corrective or other actions which have been developed by contractors, field installations and the Official-in-Charge of cognizant Headquarters Program Office and presenting the Board's conclusions as to their adequacy to the Deputy Administrator.
    - (b) Reviewing the findings during the course of investigations with cognizant field installation and Headquarters officials.
    - (c) Recommending such additional steps (for example additional tests) as are considered desirable, to determine the technical and operational causes or probable causes of failure, and to obtain evidence of nontechnical contributing factors.
    - (d) Developing recommendations for corrective and other actions, based on all information available to the Board.
    - (e) Documenting findings, determinations and recommendations for corrective or other actions and submitting such documentation to the Deputy Administrator.
- c. Procedures for implementing the Board's recommendations shall be determined by the Deputy Administrator.

6. CANCELLATION

NASA Management Manual Instruction 4-1-7 (T.S. 760), March 24, 1964.

*Rh. C. S. Smith*

Deputy Administrator

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
WASHINGTON, D.C. 20546

OFFICE OF THE ADMINISTRATOR

January 28, 1967

MEMORANDUM For the Apollo 204 Review Board

1. The Apollo 204 Review Board is hereby established in accordance with NASA Management Instruction 8621.1, dated April 14, 1966, to investigate the Apollo 204 accident which resulted in the deaths of Lt. Col. Virgil I. Grissom, Lt. Col. Edward H. White and Lt. Cmdr. Roger B. Chaffee on Launch Complex 34, on January 27, 1967.
2. The Board will report to the Administrator of the National Aeronautics and Space Administration.
3. The following are hereby appointed to the Board:
  - Dr. Floyd L. Thompson, Director, Langley Research Center,  
NASA, Chairman
  - Lt. Col. Frank Borman, Astronaut, Manned Spacecraft Center, NASA
  - Maxime Faget, Director, Engineering & Development,  
Manned Spacecraft Center, NASA
  - E. Barton Geer, Associate Chief, Flight Vehicles & Systems Division,  
Langley Research Center, NASA
  - George Jeffs, Chief Engineer, Apollo, North American Aviation, Inc.
  - Dr. Frank A. Long, PSAC Member, Vice President for Research and  
Advanced Studies, Cornell University
  - Col. Charles F. Strang, Chief of Missiles & Space Safety Division  
Air Force Inspector General  
Norton Air Force Base, California
  - George C. White, Jr., Director, Reliability & Quality, Apollo Program  
Office, Headquarters, NASA
  - John Williams, Director, Spacecraft Operations, Kennedy Space Center,  
NASA

4. George Malley, Chief Counsel, Langley Research Center, will serve as counsel to the Board.
5. The Board will:
  - a. Review the circumstances surrounding the accident to establish the probable cause or causes of the accident, including review of the findings, corrective action, and recommendations being developed by the Program Offices, Field Centers, and contractors involved.
  - b. Direct such further specific investigations as may be necessary.
  - c. Report its findings relating to the cause of the accident to the Administrator as expeditiously as possible and release such information through the Office of Public Affairs.
  - d. Consider the impact of the accident on all Apollo activities involving equipment preparation, testing, and flight operations.
  - e. Consider all other factors relating to the accident, including design, procedures, organization, and management.
  - f. Develop recommendations for corrective or other action based upon its findings and determinations.
  - g. Document its findings, determinations, and recommendations and submit a final report to the Administrator which will not be released without his approval.
6. The Board may call upon any element of NASA for support, assistance, and information.



Robert C. Seamans, Jr.  
Deputy Administrator



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON, D.C. 20546

OFFICE OF THE ADMINISTRATOR

February 3, 1967

MEMORANDUM for the Apollo 204 Review Board *je*

1. The Apollo 204 Review Board was established on January 28, 1967, in accordance with NASA Management Instruction 8621.1, dated April 14, 1966, to investigate the Apollo accident which resulted in the deaths of Lt. Col. Virgil I. Grissom, Lt. Col. Edward H. White, and Lt. Cmdr. Roger B. Chaffee on Launch Complex 34, on January 27, 1967. In order to reflect the current Board membership and to provide further guidance to the Chairman in the conduct of his duties, this memorandum supersedes that of January 28, 1967.
2. The Board will report to the Administrator of the National Aeronautics and Space Administration.
3. The following are hereby appointed to the Board:
  - Dr. Floyd L. Thompson, Director, Langley Research Center, NASA, Chairman
  - Col. Frank Borman, Astronaut, Manned Spacecraft Center, NASA
  - Maxime Faget, Director, Engineering & Development, Manned Spacecraft Ctr., NASA
  - E. Barton Geer, Associate Chief, Flight Vehicles & Systems Division, Langley Research Center, NASA
  - Col. Charles F. Strang, Chief of Missiles & Space Safety Division, Air Force Inspector General, Norton Air Force Base, California
  - George C. White, Jr., Director, Reliability & Quality, Apollo Program Office, Headquarters, NASA
  - John Williams, Director, Spacecraft Operations, Kennedy Space Center, NASA
  - Dr. Robert W. Van Dolah, Research Director for the Explosive Research Center, Bureau of Mines, Department of Interior
4. George Malley, Chief Counsel, Langley Research Center, will serve as counsel to the Board.
5. The Board will:
  - a. Review the circumstances surrounding the accident to establish the probable cause or causes of the accident, including review of the findings, corrective action, and recommendations being developed by the Program Offices, Field Centers, and contractors involved.

5.
  - b. Direct such further specific investigations as may be necessary.
  - c. Report its findings relating to the cause of the accident to the Administrator as expeditiously as possible and release such information through the Office of Public Affairs.
  - d. Consider the impact of the accident on all Apollo activities involving equipment preparation, testing, and flight operations.
  - e. Consider all other factors relating to the accident, including design, procedures, organization, and management.
  - f. Develop recommendations for corrective or other action based upon its findings and determinations.
  - g. Document its findings, determinations, and recommendations and submit a final report to the Administrator which will not be released without his approval.
6. The following amplifies and documents the verbal instructions given to the Chairman, January 28, 1967:
  - a. The Chairman shall establish such procedures for the organization and operation of the Board as he finds most effective; such procedures shall be part of the Board's records.
  - b. Board members shall be appointed or removed by the Deputy Administrator after consultation with the Chairman as necessary for the Board's effective action.
  - c. The Chairman may establish procedures to assure the execution of the Chairman's responsibility in his absence.
  - d. The Chairman shall appoint or designate such representatives, consultants, experts, liaison officers, observers, or other officials as required to support the activities of the Board. The Chairman shall define their duties and responsibilities as part of the Board's records.
  - e. The Chairman shall keep the Deputy Administrator advised periodically concerning the organization, procedures, and operations of the Board and its associated officials.
  - f. The Chairman shall assure that the counsel to the Board develops and maintains memoranda records covering areas of possible litigation.

7. The Board may call upon any element of NASA for support, assistance, and information.

*Robert C. Seamans, Jr.*

Robert C. Seamans, Jr.  
Deputy Administrator

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON, D. C. 20546

OFFICE OF THE ADMINISTRATOR

February 3, 1967

MEMORANDUM for the Apollo 204 Review Board

After consultation with the Chairman, Dr. Frank A. Long, PSAC Member, Vice President for Research and Advanced Studies, Cornell University, is no longer a member of the Apollo 204 Review Board, effective February 1, 1967.

*Robert C. Seamans, Jr.*

Robert C. Seamans, Jr.  
Deputy Administrator



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
WASHINGTON, D.C. 20546

OFFICE OF THE ADMINISTRATOR

February 3, 1967

MEMORANDUM for the Apollo 204 Review Board

Dr. Robert W. Van Dolah, Research Director for the Explosive Research Center, Bureau of Mines, Department of Interior, is hereby appointed to the Apollo 204 Review Board effective February 1, 1967.

A handwritten signature in dark ink, reading "Robert C. Seamans, Jr.", is positioned above the typed name.

Robert C. Seamans, Jr.  
Deputy Administrator



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
WASHINGTON, D.C. 20546

February 3, 1967

MEMORANDUM for the Apollo 204 Review Board

After consultation with the Chairman, Mr. George Jeffs, Chief Engineer, Apollo, North American Aviation, Inc., is no longer a member of the Apollo 204 Review Board, effective February 2, 1967.

A handwritten signature in dark ink, reading "Robert C. Seamans, Jr.", is positioned above the typed name.

Robert C. Seamans, Jr.  
Deputy Administrator

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**PART II**

**BIOGRAPHIES**

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**BIOGRAPHICAL DATA  
DR. FLOYD LAVERNE THOMPSON**

Dr. Floyd LaVerne Thompson is Director, Langley Research Center, National Aeronautics and Space Administration, Hampton, Virginia. He plans and directs research designed to provide the science and technology for a variety of important aeronautical and space programs, including the national effort to land a man on the moon and safely return him to earth. He guided research leading to a number of programs of world importance including Project Mercury, the concept of erectable space vehicles which led to the development of the world's first passive communications satellite, and the first solid fueled launch vehicle to propel a satellite into orbit.

Dr. Thompson was born in Salem, Michigan, November 25, 1898; graduated from high school in Salem in 1917 and served the following four years in the United States Navy. After his war service, he entered University of Michigan and was awarded a B. S. Degree in Aeronautical Engineering in June 1926.

He began his science career July 8, 1926, as a member of the staff of the Langley Research Center of the former National Advisory Committee for Aeronautics, nucleus of the National Aeronautics and Space Administration. Starting as an aeronautical engineer in the Flight Research Division, he progressed through various assignments to Chief of Research in 1945. He was appointed Associate Director in charge of all research September 14, 1952, and in May 1960, became Director of the Center. In addition to his duties as Langley Director, Dr. Thompson completed a two-year period of service as Chairman of the Policy Planning Board at NASA Headquarters, Washington, D. C.

He is the author or co-author of 20 technical reports based on research he conducted. He has lectured and participated in a number of technical conferences conducted by NASA, the American Institute of Aeronautics and Astronautics, the Society of Automotive Engineers and many other professional organizations. Dr. Thompson was elected in 1949 as a Fellow of the American Institute of Aeronautics and Astronautics. He is a member of the American Association for the Advancement of Science.

Dr. Thompson was cited by the University of Michigan in 1953 as a distinguished alumnus in recognition of his outstanding career in the flight sciences and honored him again in June 1963 by awarding him the honorary degree of Doctor of Science. The College of William and Mary awarded him the honorary degree of Doctor of Science in June 1963.

In May 1963, the President of the United States presented the NASA Medal for Outstanding Leadership to Dr. Thompson at ceremonies at the White House. He was honored by the NASA "for his outstanding leadership of the scientists and engineers who were responsible for the original technical concepts and who comprised the nucleus of the development team for the space flight missions of the United States in Project Mercury."

Active in civic affairs in Hampton, Virginia, and surrounding communities, Dr. Thompson is a member of the Hampton Rotary Club and the Board of Trustees of the Dixie Hospital. He is an honorary member of the Board of Directors of the Virginia Peninsula Chamber of Commerce, a trustee of The War Memorial Museum of Virginia, and an honorary life member of the Engineers' Club of the Virginia Peninsula.

Dr. Thompson lives at 94 Alleghany Road, Hampton, with his wife - the former Jean Geggie of Hampton. They have three daughters.

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**BIOGRAPHICAL DATA  
CHARLES F. STRANG  
COLONEL, USAF**

Colonel Charles F. Strang is Chief, Missile and Space Safety Division, Directorate of Aerospace Safety, Deputy Inspector General for Inspection and Safety, Headquarters, United States Air Force. In this and prior assignments, Colonel Strang has obtained extensive experience in aircraft and missile accident investigation. He was alternate President of the Air Force Board which investigated the Titan II Missile Accident of August 1965 at Little Rock Air Force Base, Arkansas.

Colonel Strang entered the United States Air Force in January 1940. He was commissioned a Second Lieutenant in March 1943 after graduation from Officer Candidate School, Miami Beach, Florida. He has served in various staff and management positions in the fields of aircraft and missile maintenance engineering and materiel. These assignments included: Chief of Maintenance, 7th Bombardment Wing, Carswell Air Force Base, Texas; Director of Materiel, 72d Bombardment Wing, Ramey Air Force Base, Puerto Rico; Deputy Director of Weapon Systems, Headquarters, 13th Strategic Missile Division, Francis E. Warren Air Force Base, Cheyenne, Wyoming; and Chief of Weapons Maintenance Management, Directorate of Materiel, Headquarters, Strategic Air Command, Omaha, Nebraska.

Colonel Strang has been awarded the Legion of Merit, the Air Force Commendation Medal with Oakleaf Cluster, the Army Commendation Medal and other Service Medals. He has served in South America, Puerto Rico and Europe.

Colonel Strang was born in Philadelphia, Pennsylvania, in 1918. He completed high school at Havertown, Pennsylvania and attended Texas Christian and Florida State Universities. In 1956, he graduated from the Air Force Command and Staff College at Maxwell Air Force Base, Alabama. He is a 1965 graduate of the Industrial College of the Armed Forces, Washington, D. C.

Colonel Strang is married to the former Mildred Irene Wells of Benton, Illinois. They have two daughters and a son. Daughter Charlene is married to Mr. R. James Mitchell of Lincoln, Nebraska. Their son, Charles II, who attends San Bernardino College, and daughter, Karen Sue, reside with the Colonel and Mrs. Strang in Redlands, California.

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**BIOGRAPHICAL DATA  
E. BARTON GEER**

Mr. E. Barton Geer has been Associate Chief of the Flight Vehicle and Systems Division, Langley Research Center, Hampton, Virginia, since 1961. He is responsible for directing and reviewing the design and development work of the three Branches of this Division covering mechanical, structural, dynamic analysis, reliability, qualification testing of spacecraft systems and subsystems. Included are considerations of thermal balance, life support, cryogenics, hypergolic, hydrogen peroxide and cold gas control systems, deployment devices, structures, dynamic vehicles and reentry and orbiting payloads.

Mr. Geer was born April 28, 1919, in Rockwell, Iowa. He attended Iowa public schools and received his Bachelor of Science Degree in Mechanical Engineering from Iowa State College in 1942, at which time he joined the Langley Research Center. From 1942 to 1950, Mr. Geer designed and developed vacuum systems, high pressure air systems, air dryers, refrigeration systems and heat exchangers. In 1950, Mr. Geer became Group Leader of the Mechanical Engineering Group and he held this position for six years. In 1956, Mr. Geer was made Head of the Systems Engineering Section, supervising twenty-five specialists and engineers in the field of thermodynamic, pressure and fluid systems. In addition, he directed the detail design of the 9 foot x 6 foot Thermal Structures air storage and supervised investigation of materials and design methods for obtaining air temperatures up to 5,000° F.

In 1960, Mr. Geer was made Branch Head of Systems Engineering Branch, consisting of 60 specialists and engineers working on systems and controls. In January 1964, Mr. Geer was named Chairman of the Scout Vehicle Design Environmental and Quality Control Committee which consisted of ten members to review the relationship among design, environment, quality control, testing and operations on the reliability of the total Scout Vehicle System. In September 1964, he was appointed Chairman of the structural, mechanical, electrical and pyrotechnic committee to review the related systems of the Pegasus Project. In 1965, Mr. Geer was appointed Chairman of a committee to review the systems, reliability and operational status of the Explorer Injun IV spacecraft. On Project Fire, he participated in the design and flight reviews of the spacecraft and directed the design and review of the tracking telespectrograph. On the Lunar Orbiter Spacecraft, Mr. Geer participated in all the Preliminary and Critical Design reviews.

He is married to the former Iris J. Carr of Fertile, Iowa, and they live at 3203 Matoaka Road, Hampton, Virginia. They have two daughters, Diane and Cheryl.

Mr. Geer is active in Civic and Church work. He is a registered professional engineer in the State of Virginia and is a member of the Engineers' Club of the Virginia Peninsula.

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**BIOGRAPHICAL DATA  
FRANK BORMAN  
COLONEL, USAF  
NASA ASTRONAUT**

Colonel Frank Borman was assigned as Commander of the third manned Apollo flight. He was Commander on the fourteen-day Gemini VII mission.

Colonel Borman entered the Air Force in June 1950 after graduation from West Point. He received his pilots' wings in 1951. From 1951 to 1956 he was assigned to various fighter squadrons in the United States and the Philippine Islands.

Colonel Borman became an assistant professor of thermodynamics and fluid mechanics at the United States Military Academy in 1957. In 1960 he graduated from the USAF Aerospace Research Pilots School. He remained there as an instructor until 1962 when he was selected by NASA as an astronaut. Colonel Borman served as back-up command pilot for the Gemini IV mission prior to flying on Gemini VII. He has accumulated over 5200 hours flying time, including 4300 hours in jet aircraft.

Colonel Borman has been awarded the NASA Exceptional Service Medal and the Air Force Command Astronaut Wings. He also received the 1966 American Astronautical Flight Achievement Award and the 1966 Air Force Association David C. Shilling Flight Trophy. He was corecipient of the 1966 Harman International Aviation Trophy.

Colonel Borman was born in Gary, Indiana on March 14, 1928, and was raised in Tucson, Arizona. He graduated from Tucson High School in 1946, the United States Military Academy in 1950 and received a Master of Science Degree (Aeronautical Engineer) from the California Institute of Technology in 1957.

Colonel Borman is married to the former Susan Bugbee of Tucson, Arizona. The Borman's have two sons, Fredrich, age 15 and Edwin, age 13.

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**BIOGRAPHICAL DATA  
GEORGE C. WHITE, JR.**

George C. White, Jr., is Director, Apollo Reliability and Quality in the Apollo Program Office, NASA Headquarters. Prior to his appointment to this position in November 1966, he was Chief, Spacecraft and Launch Vehicle Test Performance in the Apollo Test Division since December 1963. He had joined NASA in February 1963 as Chief, Command and Service Module Development.

During the period from October 1953 to February 1963, Mr. White had been with Fairchild Aircraft (now Fairchild-Hiller) in Advanced Design, Engineering Management and Program Management on the WS-123A Goose Missile and the SD-5 Surveillance Drone.

Six years, beginning in October 1947, were spent with NACA, Langley Research Center, in mechanical and structural design of rocket powered research models and special projects in the helicopter and airplane fields.

Mr. White had resigned from the Curtiss-Wright Corporation, Buffalo, New York in December 1945 to organize and manage the Dansaire Corporation where he was responsible for design, manufacture and flight test of a three place personal aircraft. He had, previous to this, been in structures engineering at Curtiss-Wright for six years, and in manufacturing at Curtiss-Wright and Piper Aircraft for a total of four years, having started at Piper in 1935.

Mr. White was born in West Grove, Pennsylvania in 1914. He received a B.S. Degree in Aeronautical Engineering from Tri-State College, Angola, Indiana, in 1937. He is married to the former Marcia C. McOmber of Bradford, Pennsylvania and they have two daughters now in college. They reside in Rockville, Maryland, where they are both active in the Rockville Presbyterian Church. Mr. White is a Registered Professional Engineer and an Associate Fellow in the AIAA and he holds a Commercial Pilot's License.

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**BIOGRAPHICAL DATA**  
**DR. ROBERT WAYNE VAN DOLAH**

Dr. Robert Wayne Van Dolah is Research Director, Explosive Research Center, Bureau of Mines, U.S. Department of Interior, Pittsburgh, Pennsylvania. In this position which he has occupied over twelve years, he plans and directs research in the fields of combustion, explosions and explosives. In addition to the programs supported by direct appropriation, he directs investigations related to a variety of space, military and private industry problems in the field of combustion and explosions. He has provided consultative service to military agencies on a number of occasions. He has participated in several accident investigations involving fire and explosions.

Prior to joining the Bureau of Mines in 1954, Dr. Van Dolah was head of the Organic Chemistry Branch and then head of the Chemistry Division at the U.S. Naval Ordnance Test Station beginning in 1946. In those positions he planned and directed research on the chemistry of propellants and fuels and their combustion characteristics. Before that he served first as assistant to the Scientific Director and later as research Chemist and Group Leader of the William S. Merrell Company, Cincinnati, Ohio.

Dr. Van Dolah was born in Cheyenne, Wyoming, February 1, 1919. He received a Bachelor of Arts Degree in Chemistry from Whitman College, Walla Walla, Washington, in 1940 and a Ph.D. in Organic Chemistry from the Ohio State University, Columbus, Ohio, in 1943. He is a member of the honorary societies: Phi Beta Kappa, Phi Lambda Upsilon and Sigma Xi; and of the professional societies: American Chemical Society, American Association for the Advancement of Science (Fellow), Combustion Institute, American Institute of Aeronautics and Astronautics (Senior Member). He is on the Board of Directors of the National Fire Protection Association.

Dr. Van Dolah is author or co-author of 97 publications and three patents. He is very active in committee work in areas relating to fire and explosions including being Chairman of National Fire Protection Association Committee on Chemicals and Explosives, the Working Group on Hazards, Committee on Safety Criteria of the Interagency Chemical Rocket Propulsion Group. He is a member of American Chemical Society Committee on Chemical Safety and of numerous other committees. In July 1965, he received the Department of Interior Distinguished Service Award.

Dr. Van Dolah lives at 202 Cherokee Road, Upper St. Clair Township (Pittsburgh), Pennsylvania, with his wife, the former Elizabeth M. Becker of Portland, Oregon. They have one daughter in college and two sons in high school.

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**BIOGRAPHICAL DATA  
JOHN J. WILLIAMS**

John J. Williams, Director, Spacecraft Operations, John F. Kennedy Space Center, is responsible to the Director of Launch Operations for the management and technical integration of KSC operations related to preparation, checkout and flight readiness of manned spacecraft.

Since joining the National Aeronautics and Space Administration in 1959, Mr. Williams was the Head of Capsule Systems Branch during the Mercury Program and was the Assistant Manager for Gemini, MSC-Florida Operations until he was moved to his current position in December 1964.

From 1954 to 1959 he was employed by the U.S. Air Force as an electronic engineer in the Directorate of Test Engineering, Air Force Missile Test Center, Florida. He was responsible for the evaluation of various missile prelaunch and flight tests.

From 1951 to 1954 Mr. Williams was employed as an electronic engineer in the Technical Systems Laboratory, Air Force Missile Test Center, Fla., where he was engaged in ground instrumentation and antenna fabrication and testing.

Mr. Williams was employed as an electronic engineer by the U.S. Air Force at Wright Patterson Air Force Base, Dayton, Ohio. He engaged in the development of a cooling system for electronic devices at extremely high altitudes and in the miniaturization of airborne power supplies.

Mr. Williams, a native of New Orleans, Louisiana, graduated from high school in 1944. He served in the U.S. Navy during World War II as an electronic technician and upon his discharge from service entered Louisiana State University. He graduated in 1949, receiving a Bachelor of Science Degree in Electrical Engineering.

Mr. Williams and his organization won many honors, receiving the Group Achievement Award in 1966 for contribution to the success of the Gemini VII/VI Launch Operations and to the success of Project Gemini. In 1966 Dr. Seamans presented him the Outstanding Leadership medal for his work in Manned Space Programs.

He now lives in Eau Gallie, Florida, with his wife, Peggy; daughters, Barbara and Jo Ann; and son Michael.

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**BIOGRAPHICAL DATA**  
**DR. MAXIME A. FAGET**

Dr. Maxime A. Faget has been the Director of Engineering and Development, Manned Spacecraft Center, National Aeronautics and Space Administration, Houston, Texas, since February 1962. He is responsible for technical support of the Gemini and Apollo manned space flight programs and advanced studies into space systems. As a NASA member of the Polaris Missile Steering Task Group, he contributed to the design of that Navy missile. Dr. Faget served on the Steering Committee which helped the NASA Administrator make Project Mercury policy decisions.

Dr. Faget was born at Stann Creek, British Honduras, August 26, 1921. He attended San Francisco, California, Junior College and received a Bachelor of Science degree in Mechanical Engineering from Louisiana State University. He served three years as a naval officer during World War II.

Dr. Faget joined the staff of Langley Research Center, NASA, in 1946 as a research scientist. He worked in the Pilotless Aircraft Research Division; later was named head of the Performance Aerodynamics Branch. He conceived and proposed the development of a one-man spacecraft, later used in Project Mercury. Dr. Faget was one of the original group of 35, assigned as a nucleus of the Space Task Group to carry out the Mercury project.

Dr. Faget has authored and co-authored numerous technical papers on aerodynamics, rocketry, high-speed bomb ejection, reentry theory, heat transfer, and aircraft performance. He is co-author of a textbook, "Engineering Design and Operation of Spacecraft," and is author of a book entitled, "Manned Space Flight." Dr. Faget holds joint patents on the "Aerial Capsule Emergency Separation Device" (escape tower), the "Survival Couch," the "Mercury Capsule," and a "Mach Number Indicator."

Dr. Faget is a member of the following: Tau Beta Pi, National Engineering Honor Society; Omicron Delta Kappa, National Leadership Honor Society; International Academy of Astronautics of the International Astronautical Federation. He is an Associate Fellow, American Institute of Aeronautics and Astronautics.

Dr. Faget was presented the Arthur S. Fleming Award in 1960. He was presented the Golden Plate Award in 1961 by the Academy of Achievement. In 1963 he was awarded the NASA Medal for Outstanding Leadership and in 1965 he was presented the Award of Loyola. Dr. Faget was honored by the University of Pittsburg, March 1966 by awarding him the Honorary Degree of Doctor of Engineering. Dr. Faget served as visiting Professor teaching graduate level courses at the Louisiana State University, Rice University and the University of Houston.

Dr. Faget is married to the former Nancy Carastro of Philadelphia, Pennsylvania. They reside with their 3 daughters - Ann Lee, Carol Lee and Nanette, and son, Guy, at Dickinson, Texas.

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**BIOGRAPHICAL DATA**  
**GEORGE T. MALLEY**  
**Counsel to the Board**

Born April 24, 1913, Rochester, New York. Attended public and parochial schools in Rochester and received A.B. Degree from the University of Rochester, and L.L.B. Degree from Cornell University, Ithaca, New York.

Member of the New York Bar.

Attorney, Office of General Counsel, Department of the Navy – 1950 to 1959.

Chief Counsel, Langley Research Center, National Aeronautics and Space Administration, 1959 to present.

Retired Naval Reserve Officer – Active duty World War II – 1939 to 1946, chiefly in South Pacific serving on various types of ships.

Married to Sally E. Wren, 2 step-sons, resident of Newport News, Virginia.

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**PART III**

**BOARD**

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

February 4, 1967

MEMORANDUM FOR RECORD

SUBJECT : Establishment of Apollo 204 Review Board Advisory Group

REFERENCE: Memorandum for the Apollo 204 Review Board from Dr. Robert C. Seamans, Jr., Deputy Administrator, NASA, dated February 3, 1967

1. An Advisory Group is hereby established to support the Apollo 204 Review Board in its investigation. This Group consists of Representatives, Consultants, Liaison Officers, Observers, and Secretariat.
2. The Advisory Group will report to the Chairman, Apollo 204 Review Board.
3. The Advisory Group will consist of:
  - a. Representative: Represent a major element of NASA or other Government agency having programs and activities associated with the Apollo Program.
  - b. Consultant: Serve as an advisor to Apollo 204 Review Board by providing views, opinions, information, and recommendations, as appropriate, based on his field of competence.
  - c. Liaison Officer: Represent an activity having an interest in the Apollo 204 review and provide liaison with that activity by the acquisition of information.
  - d. Observer: Acquire information relative to his area of expertise and normal responsibility.
  - e. Secretariat: Provide administrative, secretarial, clerical, and other supporting services to the Review Board.

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4. The following are hereby designated the Advisory Group:

Representatives

Gen. C. H. Bolender	OMSF, represents Apollo Program Director
Mr. C. Mathews	OMSF, Director, Apollo Applications Program
Mr. R. A. Petrone	KSC, Director, Launch Operations
Dr. J. Shea	MSC, Manager, Apollo Spacecraft Program Office
Lt. Col. W. Baxter	USAF, Chief, Range Safety Office, Air Force Eastern Test Range
Dr. G. F. Kelly	Flight Medicine Branch, Center Medical Office, MSC

Consultants

Dr. Frank A. Long	Vice President for Research and Advanced Studies, Cornell University
Mr. J. Yardley	Technical Director, Astronautics Company, Division of McDonnell Company
Mr. G. W. Jeffs	Chief Engineer, Apollo Program, North American Aviation, Inc.
Alternate: Mr. R. L. Benner	Assistant Chief, Engineer, Apollo Program, North American Aviation, Inc.
Mr. Irving Pinkel	Chief, Fluid Systems Research Division, Lewis Research Center
Mr. Thomas G. Horeff	Propulsion Program Manager, Engineering and Safety Division, Aircraft Development Service, Federal Aviation Agency
Dr. H. Carhart	Chief, Fuels Branch, Chemistry Division, Naval Research Laboratory
Mr. John S. Leak	Chief, Technical Services Section, Engineering Division, Bureau of Safety, Civil Aeronautics Board

Liaison

Mr. Duncan Collins                      Special Advisor, Secretary of the Air  
Force, SL Program

Observers

All Astronauts, MSC  
Maj. P. A. Butler, USAF  
Dr. Kurt H. Debus, KSC  
Mr. P. C. Donnelly, KSC  
Lt. Col. W. Dugan, USAF  
Mr. John Hodge, MSC  
Mr. J. King, KSC  
Mr. H. E. McCoy, KSC  
Mr. R. E. Moser, KSC  
Dr. George Mueller, OMSF  
Mr. W. P. Murphy, KSC  
Gen. S. C. Phillips, OMSF  
Mr. G. M. Preston, KSC  
Gen. J. G. Shinkle, KSC  
Mr. A. F. Siepert, KSC  
Mr. W. Williams, KSC

Secretariat

Mr. Ernest Swieda

Executive Secretary

  
Dr. Floyd L. Thompson  
Chairman  
Apollo 204 Review Board

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

February 7, 1967

MEMORANDUM FOR RECORD;

SUBJECT : Establishment of Apollo 204 Review Board Panels

REFERENCE: Memorandum for the Apollo 204 Review Board from  
the Deputy Administrator, NASA, dated February 3, 1967

1. Task Panels are hereby established to support the Apollo 204 Review Board in its investigation. A Board member, appointed by the Chairman, will serve as Monitor for each Panel.
2. The Task Panels will report to the Chairman, Apollo 204 Review Board.
3. The Panels, under the direction of their Chairmen appointed by the Board Chairman will:
  - a. Perform all functions within their respective statements of work as approved by the appropriate Board Monitors.
  - b. Submit work plans through the Panel Coordination Committee to the Review Board for approval.
  - c. Provide reports to the Review Board, when required, on the progress of work.
  - d. Work with each other under the cognizance and guidance of the Panel Coordination Committee.
4. The following Panels are hereby designated, together with respective appointed Panel Chairmen and Board Monitors:

PANEL NO.	PANEL TITLE	PANEL CHAIRMAN	BOARD MONITOR
1	S/C and GSE Configuration	J. Goree, MSC	J. Williams, KSC
2	Test Environments	W. Hoyer, MSC	G. White, NASA Hqs
3	Sequence of Events	D. Arabian, MSC	Dr. M. Faget, MSC
4	Disassembly Activities	S. Simpkinson, MSC	Col. F. Borman, MSC

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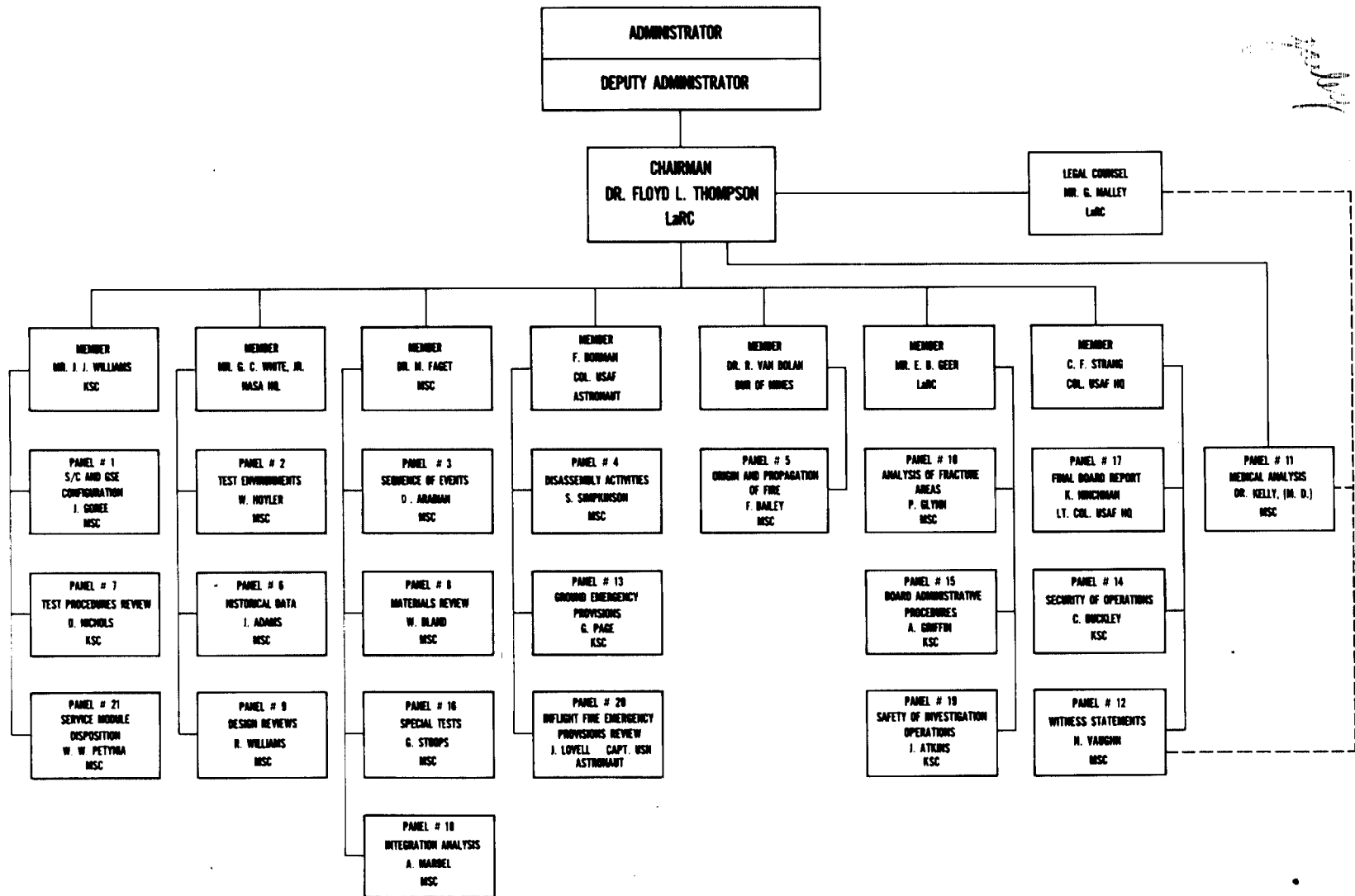
PANEL NO.	PANEL TITLE	PANEL CHAIRMAN	BOARD MONITOR
5	Origin & Propagation of Fire	F. Bailey, MSC	Dr. Van Dolah
6	Historical Data	J. T. Adams, MSC	G. White, NASA Hqs
7	Test Procedures Review	D. Nichols, KSC	J. Williams, KSC
8	Materials Review	W. Bland, MSC	Dr. M. Faget, MSC
9	Design Reviews	R. Williams, MSC	G. White, NASA Hqs
10	Analysis of Fracture Areas	P. Glynn, MSC	B. Geer, NASA LaRC
11	Medical Analysis	G. Kelly, MSC	Dr. F. Thompson, NASA LaRC G. Malley, Counsel
12	Witness Statement	N. Vaughn, MSC	Col. C. Strang, USAF G. Malley, Counsel
13	Ground Emergency Provisions Review	G. Page, KSC	Col. F. Borman, MSC
14	Security of Operations	C. Buckley, KSC	Col. C. Strang, USAF
15	Board Administrative Procedures	A. Griffin, KSC	B. Geer, LaRC
16	Special Tests	G. Stoops, MSC	Dr. M. Faget, MSC
17	Final Board Report	Lt. Col. K. H. Hinchman, USAF	Col. C. Strang, USAF
18	Integration Analysis	A. Mardel, MSC	Dr. M. Faget, MSC
19	Safety of Investigation Operations	J. Atkins, KSC	B. Geer, NASA LaRC
20	In Flight Fire Emergency Provisions Review	Capt. J. Lovell MSC	Col. Borman, MSC
21	Service Module Disposition	W. W. Petynia, MSC	J. Williams, KSC

  
 Dr. Floyd C. Thompson  
 Chairman  
 Apollo 204 Review Board



# NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

## APOLLO 204 REVIEW BOARD AUTHORITY



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## BOARD PROCEDURES

The Apollo 204 Review Board was established by the Administrator, National Aeronautics and Space Administration, under the authority of NASA Management Instruction 8621.1, dated April 14, 1966. Dr. Robert C. Seamans, Jr., Deputy Administrator, NASA, in Memoranda dated January 28, 1967, and February 3, 1967, appointed Board Members, defined Board responsibilities and amplified oral instructions to the Board Chairman, Dr. Floyd L. Thompson.

The Board was composed of eight members, including the Chairman. Six members were NASA personnel; one member was an officer from the Aerospace Safety Directorate of the Air Force Inspector General and one member was from the Bureau of Mines, Department of Interior. A Counsel was assigned to provide legal advice.

Twenty-one Task Panels were formed, each reporting to a Monitor who was a Board Member. Task Panels were assigned the responsibility of providing administrative assistance and technical investigation for the Board. Each Panel, with the exception of the Final Board Report Panel, was chaired by NASA personnel experienced in the area of interest of that particular Panel. The Final Board Report Panel was chaired by an Air Force Officer. Each Panel was manned by NASA personnel assisted by contractor personnel in defined technical areas.

In addition, Representatives, Consultants and Observers participated in General Board Meetings and Panel activities. These individuals assisted the Panels and Board Members in their area of expertise and responsibilities.

The established procedure for the Board was to convene a General Session Daily at 10:30 a.m. for approximately one hour. During these meetings, plans and schedules were reviewed. Reports on proposed actions were presented for approval of plans and schedules and the determination of requirements for testing and analyses.

An Executive Session was held each afternoon at 4:00 p.m. This Meeting was restricted to Board Members; however, additional personnel were requested to attend when necessary.

Basic direction to all Board activities was developed and consummated during Executive Sessions. The Executive Sessions provided the Board the opportunity to freely discuss sensitive matters. Plans, schedules and other investigating actions were formally approved by the Board in these Sessions.

Operational procedures for the activities of the Board, the Advisory Group and supporting personnel were delineated in a series of Administrative Procedures authorized by the Chairman of the Board.

The investigation techniques employed by the Board required the coordinated effort of numerous agencies. An overall Master Plan was developed to insure that the investigation was accomplished systematically without disturbing or destroying evidence. This plan required disassembly of the Spacecraft on a component or system basis with continual observation by appropriate Panel personnel and photography before, during and after the removal of each component. The technique of disassembly was validated in Spacecraft 014 Command Module prior to the actual component removal from Spacecraft 012 Command Module involved in the accident. During the disassembly, extreme caution was exercised to prevent disruption of adjacent areas. As components were removed they were identified and placed in a bonded area and made available for inspection as authorized by the Board.

Simultaneously with Spacecraft disassembly, extensive testing and numerous analyses were accomplished. These tests and analyses were accomplished by many agencies: i.e., Kennedy Space Center, Manned Spacecraft Center, United States Air Force, Bell Laboratories, contractors, sub-contractors

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## BOARD PROCEDURES

and vendors. All Telemetry data, Spacecraft Records, and Design Documents were reviewed in detail. When anomalies were discovered, they were analyzed completely to determine their relationship to the accident.

The investigation technique also provided rigid control for all material associated with the review. Immediately after the accident, all possible relevant material was impounded. This material was analyzed in detail and released only after determination that it did not contribute to the accident or was no longer required by the Apollo 204 Review Board

The Final Report of the Apollo 204 Review Board was designated to document the findings, determinations and recommendations for submission to the Administrator, National Aeronautics and Space Administration.

A General File of the materials of the Apollo 204 Review Board investigation has been established. The Director, Langley Research Center, NASA, Virginia, has been designated the custodian of the file. The General File containing Telemetry Data, Spacecraft Design Records, Data from special tests and analyses conducted, and other documents relating to the investigation will be physically located at Langley Research Center. The Spacecraft, related hardware and drawings, residue from the fire and Astronaut's equipment will be stored at Kennedy Space Center with the Manager, Apollo Spacecraft Program Office, Manned Spacecraft Center, Houston, Texas, acting as custodial agent for the Langley Research Center. Medical records specifically associated with the investigation will be stored at Manned Spacecraft Center, in custody of the Director of Medical Research and Operations, who is Custodial Agent for Langley Research Center. All materials in the General File will be securely stored at the designated locations for a period of ten years, unless sooner released by proper authority.



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

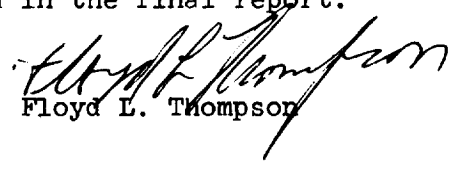
February 8, 1967

IN REPLY REFER TO Chairman, Apollo 204 Review Board

TO: DISTRIBUTION

SUBJECT: Transcripts of Review Board Sessions

1. During the first days of the sessions of the Apollo 204 Review Board, the Board heard discussion, suggestions, extemporaneous remarks by Board members, Advisory Group members and technical experts engaged in studies relevant to the review, and accounts, to be verified, from two on-the-scene witnesses and one individual who was observing the monitors in the blockhouse.
2. In the free and open discussion, in many cases the identity of the speakers was not established and the remarks were not clearly related to the subject under discussion. The result is that the transcript of the proceedings of the first days (other than eye witness accounts) is valuable primarily as background material that provides a useful source for identifying potential review action.
3. In view of the foregoing, the minutes of the Review Board meetings on January 28, 29, and 30 will be utilized only as reference material with limited distribution, with the exception of identifiable eye witness accounts which will be appropriately incorporated in the final report.

  
Dr. Floyd L. Thompson

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Note: The Board Proceedings are the highlights of Board activities. Complete transcripts of General Sessions of the Apollo 204 Review Board are contained in Appendix A.

#### **January 28, 1967**

(1) The Chairman and several Members of the Board assembled at Kennedy Space Center (KSC) at midday, January 28 and met with the Deputy Administrator, Dr. Robert C. Seamans, Jr.; the Apollo Program Director, Major General Samuel C. Phillips; and other officials from NASA Headquarters, the Manned Spacecraft Center (MSC) and Kennedy Space Center. These NASA officials provided a quick appraisal of the circumstances surrounding the accident and actions already taken at KSC. This meeting was followed by an initial general session of the Board in the Mission Briefing Room, a secure area used to conduct Board business.

(2) After a general discussion, the meeting was adjourned to permit the Board to visit the scene of the accident at Launch Complex (LC) 34. Upon completion of this inspection, the Board reconvened in general session and initiated detailed procedural planning for conduct of the Review.

#### **January 29, 1967**

(1) Colonel Frank Borman briefed the Board on his inspection of the Spacecraft (Command and Service Modules). The purpose of this inspection was to verify the position of circuit breakers, switches, etc. Immediately following the inspection, many photographs were taken of the exterior and interior of the Command Module (C/M) with emphasis on switches and circuit breaker panels.

(2) The Board interviewed Mr. Donald O. Babbitt for approximately 45 minutes and Mr. James D. Gleaves for approximately 30 minutes. Both are employees of North American Aviation, Inc. (NAA) and were on level A-8 of LC 34 at the time of the Apollo 204 accident.

(3) The Pyrotechnic Installation Building (PIB) was assigned to the Board to display the debris and Spacecraft (S/C) components after removal from the Launch Complex.

(4) Dr. Thompson, Board Chairman, asked Dr. George E. Mueller, Associate Administrator for Manned Space Flight (who was at KSC), for assistance in obtaining flame propagation experts to assist the Apollo 204 Review Board. Dr. Thompson suggested these experts might be obtained from the following organizations:

- a. Lewis Research Laboratory, NASA
- b. Bureau of Mines
- c. Federal Aviation Agency

(5) Dr. Thompson authorized selected personnel from the local press pool to photograph and observe the C/M. Dr. Thompson authorized one still and one motion picture photographer with one writer representative to visit LC 34. They were escorted by Mr. Charles L. Buckley, Jr., Chief, Security Office, KSC and Mr. John W. King, Chief, Public Information Office, KSC. Dr. Thompson instructed Mr. Buckley and Mr. King to restrict the press personnel to photography and observation and not allow any questions pertaining to the accident.

(6) Dr. Thompson established an ad hoc committee composed of Mr. John J. Williams, Mr. E. Barton Geer, Mr. Charles Mathews, Mr. John F. Yardley, Mr. George Jeffs and Colonel Charles F. Strang. They were to organize Task Panels to accomplish the accident investigation in a systematic manner.

**January 30, 1967**

(1) Dr. Robert W. Van Dolah, Bureau of Mines, Mr. I. Irving Pinkel, Lewis Research Center, Mr. T. Horeff, Federal Aviation Agency, joined the Apollo 204 Review Board as Consultants.

(2) Membership on the special ad hoc committee that was established on January 29, 1967 to make recommendations on the types of special Panels was changed to: Colonel Borman, Mr. Jeffs, Mr. Yardley, Mr. Mathews, Dr. Maxime A. Faget and Mr. Williams, Chairman. Dr. Thompson directed that the assignment of tasks will be supported by a statement of work, i.e., "guidelines and basis for understanding." Mr. Mathews presented an oral outline of the 19 recommended Panels and the work objectives of each. A Board Member was assigned to monitor each Panel and to serve as the focal point through which the Panels would report to the Board.

(3) Dr. Thompson designated Colonel Strang to assume the responsibility of managing the assembly of all information and data that will be embodied in the Final Report. Colonel Strang was also assigned to plan the format of the Report.

(4) Lt. Colonel James W. Rawers, Range Safety Division, Analysis Section, presented on oral report on what the Air Force Eastern Test Range (AFETR) personnel saw at the time of the accident.

(5) Dr. Thompson announced that Mr. George T. Malley, Chief Counsel at Langley Research Center, will serve as Counsel for the Board.

(6) Dr. Faget introduced Mr. Alfred D. Mardel, who presented a briefing on data and sequence of events.

**January 31, 1967**

(1) Dr. Thompson received from Dr. Seamans a "Memorandum for the Apollo 204 Review Board" dated January 28, 1967, which established the Review Board. Dr. Thompson discussed the memorandum at length and made distribution of copies to all Board Members.

(2) The Board was advised by Colonel Strang that the accident which occurred in an altitude chamber at Brooks Air Force Base, Texas on January 31, 1967, might be of particular interest to the Board. He presented a short briefing of the circumstances. The Chairman requested Colonel Strang to provide follow-up for the Board.

(3) Lt. Colonel William D. Baxter (AFETR Representative to the Board), advised of existing hazards associated with the spacecraft. These included: high pressure oxygen bottles which may be pressurized to 485 pounds per square inch (psi) and subject to embrittlement; pyrotechnics on the Service Module; and the Launch Escape System (LES), which has a 9000 pound thrust rocket motor. An engineering review was made of these potential hazards and it was agreed that before any work could proceed, these specific items must be removed.

(4) A technical briefing on telemetry data, recorded prior to and during the accident was presented to the Board. These data indicate discrepancies in certain channels. Therefore, without further evaluation, the telemetry data are inconclusive.

(5) In lieu of classifying Review Board records as confidential, a special cover sheet will be used to comply with the Chairman's instruction that all Apollo 204 Review Board records and material be treated as "Confidential." A supply of these cover sheets was provided.

(6) The Chairman of Panel 4, Disassembly Activities, presented a briefing on the Spacecraft Debris Removal Plan. The Board approved the plan to the point of removing the astronauts' couches.



(7) Panel 19, Safety of Investigation Operations, was formed.

**February 1, 1967**

(1) The task of removal of the Launch Escape System was delayed until retro rockets and other ordnance devices could be removed from the Saturn Launch Vehicle (SLV) and Spacecraft.

(2) Dr. Van Dolah, Bureau of Mines, replaced Dr. Frank A. Long, Vice President for Research and Advanced Studies, Cornell University, as a Member of the Board. Dr. Long, whose other responsibilities precluded full time service with the Board, will continue to serve as a Consultant. (Dr. Van Dolah was assigned the responsibility of Panel Monitor for the Panel on Origin and Propagation of Fire.)

(3) Dr. Thompson appointed a committee, composed of two Board Members and three Consultants, to coordinate Panel activities and bring to the attention of the Board those actions requiring specific approval. This group will be known as the Panel Coordinating Committee and be required to present daily activity reports to the Board. This committee supplanted the ad hoc committee that had planned the organization of the Panels. A procedure was established for orderly, controlled (numerically sequenced from 0001) presentation of proposed "Action Items" to the Board for approval prior to implementation of hardware removal, special tests and other Review Board activities.

(4) Proposed Action Items 0001-0007 were presented for consideration by the Board. 0001-0006 were approved, 0007 was deferred.

(5) The Board reviewed the methods used in releasing public statements. Dr. Thompson advised that no public statements will be made until approved by him.

(6) Colonel Strang briefed the Board on a proposed Final Report format. It was necessary that a Report format be approved at an early date in order that an orderly flow of data from the Panels could be maintained. The proposed Final Report format was a modified version of the one used by the Air Force for accident investigations. The proposal was tentatively accepted.

(7) Colonel Strang requested copies of all witness statements be provided each Board Member as they are developed. This will permit a prompt review so that additional interviews can be arranged if necessary.

(8) Dr. Thompson announced an Executive Session (Board Members) will be held daily at 4:00 p.m.

(9) Dr. Faget presented a status report on work in progress. He outlined the daily reports as follows:

- a. Activities accomplished on the Launch Complex and in other related areas,
- b. Items needing Board approval for future activities,
- c. Progress analysis and anticipated work.

**February 2, 1967**

(1) Dr. Seamans attended the General Board Session. He reiterated and emphasized that all news releases would be made through the Board Chairman.

(2) Dr. Thompson announced that Mr. Jeffs had been appointed a Consultant in lieu of Board membership.

(3) Command Module 014 arrived from Downey, California and is in place at the Pyrotechnic In-

stallation Building (PIB), KSC. This Module will be used for training of technicians who will disassemble C/M 012; i.e., prior to the removal of any component from 012, the technicians will perform similar tasks on 014. In this way, they will become familiar with all actions required to remove any single component. Consequently, little or no damage or disruption will take place during the removal of items from 012 as it is disassembled. As a component is removed, it will be transported from the LC and placed in the PIB. It was agreed that all equipment associated with the accident will also be located in the PIB. This includes Command Module hardware and support equipment. Spacesuits and other associated flight equipment will be placed in a special room within the PIB where strict access control will be maintained.

(4) The most significant event to date was the removal of the Launch Escape System from the Command Module, thereby removing the greatest potential hazard to disassembly operations. With this task completed, it is estimated that members of the Fire Propagation Panel will enter the Command Module on February 3, 1967. Completion of the Launch Escape System removal will also permit extensive photographic coverage of the inside of the Command Module.

(5) Colonel Strang distributed copies of a status report on the recent accident at Brooks Air Force Base for the Board's information. He stated that authority had been received from the Chief of Staff, USAF, for him to maintain direct contact with the Accident Investigation Board at Brooks AFB.

(6) Mr. Malley, Counsel for the Board, was requested to prepare a statement to be read to each witness prior to making a statement. It will inform the witness of the Board's precise intention with respect to use of the statement.

(7) Proposed Action Items 0008 - 0024 were presented for consideration and approved by the Board.

(8) The matter of samples for analysis was again brought up and it was decided as a general directive that samples be reserved to provide for testing by two outside or independent agencies. If certain conditions make this impossible, appropriate action should be brought back to the Board for approval.

#### **February 3, 1967**

(1) The Chairman announced he had received a telephonic draft of the revised authority from NASA under which the Board is to be conducted. He also explained to the Board that this new authorization grants him, as Chairman, the authority to change the composition of the Board advisory group, to appoint an Acting Chairman and appoint any other positions of the advisory group he deems necessary. Dr. Thompson appointed Colonel Strang to serve as Acting Chairman in the absence of the Chairman.

(2) The Board reviewed the Lockheed Aircraft Corporation film entitled, "Investigation Report, Aircraft Wire Harness Fires, Revision 2." Through telephone conversations with Colonel Strang and Mr. Malley, Mr. Gilley, Lockheed Georgia Company of the Lockheed Aircraft Corporation, granted permission for the Board to reproduce the film and copies of the report thereto. Three Panels requested copies of the reports, which were made available.

(3) Dr. Thompson requested a document be written establishing procedures for entry to Command Module 012. Coordination of requirements and priorities will be controlled by the Panel Coordinating Committee. Entry to the C/M will be controlled by Colonel Borman or his delegated representative.

(4) A sequence of events display (immediately preceding and following the accident) was prepared from telemetry data and positioned in the Mission Briefing Room. The time span of the display is from 23:30 to 23:33 hours, Greenwich Mean Time (6:30 to 6:33 p.m. EST) on January 27, 1967. Significant information on several spacecraft systems such as communications, instrumentation, electrical power, environmental control, guidance and navigation and stabilization and control is included on the display.

It will be updated as additional data are analyzed and will be available for easy reference by Board Members.

(5) Dr. Thompson requested that Board Members have their Panel Chairmen submit work requirements and priorities in writing to the Panel Coordination Committee so a schedule can be developed.

(6) Colonel Borman reported that the Debris Removal Plan, as approved by the Board, had progressed satisfactorily. The next phase will involve the use of protective covers (plywood) for the couches so detailed examinations of the C/M interior can be accomplished.

(7) Proposed Action Items 0025 - 0027 were presented and approved by the Board.

(8) Procedures to further control entry to the Command Module, Launch Complex 34 and the Pyrotechnic Installation Building were approved by the Board.

(9) Dr. Homer Carhart, Chief of Fuels Research, Chemistry Division, Naval Research Laboratory, Washington, D. C., was assigned to the Fire Propagation Panel.

(10) Dr. Thompson appointed the following as Representatives to the Board: Brig. General C. H. Bolender, USAF and Mr. Charles Mathews, NASA, Washington, D.C.; Dr. Joseph F. Shea and Dr. G. Fred Kelly (M.D.), MSC; Mr. Rocco Petrone, KSC; Lt. Colonel William D. Baxter, Air Force Eastern Test Range.

#### **February 4, 1967**

(1) Dr. Thompson asked the Board Members to support the Public Information Office (PIO) in obtaining photographs to keep the public informed of activities and progress.

(2) A system was established to ensure that all recommendations and offers of assistance received by NASA, regardless of source, be referred to the Review Board for appropriate action and acknowledgment.

(3) A draft report of the use of internal/external power on the C/M was distributed by Dr. Faget for the Board's information.

(4) Dr. Thompson stated that the list of advisory groups (Representatives, Observers, Liaison, Consultants) is being prepared. The individuals assigned to these advisory groups will be identified within their respective organizations and by position held in that organization.

(5) Dr. Thompson directed Mr. Williams to develop an overall master plan including important milestones and estimated time frames. He called a meeting following today's General Board Session to discuss this with Mr. Williams and some of his committee members.

(6) Mr. Scott Simpkinson, Panel 4 Chairman, presented and distributed the disassembly schedule. He estimated removal of the couches from C/M 012 by 5:00 a.m., and installation of the false floor by 12:00, February 5. This false floor was installed in C/M 014 last night as an exercise prior to having it installed in C/M 012.

(7) Colonel Borman asked for and was permitted release of the impounded flight suits of the backup crew for use in an egress test. The Board will view this test in the Simulator Building, Sunday, February 5, at 10:00 a.m.

**February 5, 1967**

(1) Members, Consultants and Observers of the Board visited the Spacecraft Simulator. The simulator performs many functions including navigation, earth observation and inflight procedures. At the time of the visit three astronauts were practicing inflight emergency procedures. One of the procedures was donning the space suits. This was carefully timed and required a total of 12 minutes to perform the task. Two astronauts gave a detailed briefing on the composition, function and operating procedures for all components of the space suit. The Board Members also inspected the inside of the simulator which is configured to duplicate Spacecraft 012 in most areas.

(2) Dr. Thompson, Mr. Geer and Mr. Malley departed for Langley Research Center, Virginia. They are scheduled to return in the late afternoon on February 6, 1967. In accordance with Dr. Thompson's previous instructions, Colonel Strang served as Acting Chairman of the Board.

(3) Representatives of the Board visited Launch Complex 34 and made a very detailed inspection of movable platforms A-7 and A-8 which surrounded the Apollo Spacecraft. During this inspection, the installation of the false floor in the Command Module was observed. Since removal of the astronauts' couches a false floor was constructed and suspended from the Command Module ceiling and entrance hatch. This will facilitate inspection of the floor of the module without disturbing any evidence of the fire damage.

**February 6, 1967**

(1) Colonel Strang, acting for Dr. Thompson, conducted the General Session.

(2) The Master Plan Milestone Display was distributed and explained by Mr. Williams. The Systems Integration Panel will prepare a Phase "A" plan today and submit same for Board approval. The Board Members were asked to review this Master Plan with their Panel Chairmen and provide comments to Dr. Thompson.

(3) Lt. Colonel Baxter reported the status of the Witness Statements as of 10:30 a.m., February 6. There were 90 statements; the original package distributed on February 2, the first addition on February 3 and the third and fourth addition on February 4 and 6 respectively. The distribution list is amended to include copies for Panels 6, 14, 17 and 18.

(4) Mr. Jeffs announced that a team made up of representatives of AiResearch and North American Aviation, Inc., arrived at KSC on February 6 to inspect the Command Module and to propose further action relative to the Environmental Control Unit (ECU) and Environmental Control System (ECS).

(5) Reconsideration was requested of Action Item 0007, Medical Data Acquisition System Removal, that was presented to the Board on February 1 and deferred at that time. Technicians are now prepared to remove the tape recorder from the C/M and remove the tapes for analysis. Action Item 0028 was distributed to the Board. Approval was granted for work to proceed on both Items 0007 and 0028, providing that appropriate members of Panels 4 and 5 are present.

(6) Colonel Strang stated that Dr. Thompson had requested that the "Life Sciences" part of the Final Report include an analysis of the escape system and appropriate re-design recommendations. This system falls within the purview of the Ground Emergency Procedures Review Panel 13, the In-flight Fire Emergency Provisions Review Panel 20 and the Design Review Panel 9 in addition to the Medical Analysis Panel 11. Dr. G. Fred Kelly, Chairman of Panel 11, was requested to coordinate and interface the findings of the above Panels.

## **February 7, 1967**

(1) The Board received a detailed preliminary report from Mr. Pinkel, a Member of the Fire Propagation Panel. This report described the areas of the Command Module (C/M) which received the greatest fire damage, the most probable fire paths and a description of combustible material in the C/M. He stated the oxygen available in the C/M would permit burning of only 12-15 lbs. of combustible material. Solid combustible materials used in the C/M includes plastics in the nylon, polyurethane and silicone rubber class. The liquid coolant ethylene glycol could also become a fuel if it escaped from the closed coolant system. Additional inspections and investigations are required by this Panel to develop conclusive findings.

(2) Request for approval of Action Items 0029 through 0052, approved by the Board at the Executive Sessions held February 6 and 7 were read for the record by Mr. Williams.

(3) A technical team from AiResearch Company and North American Aviation, Inc., under NASA supervision, completed an inspection of the Environment Control Unit in C/M 012, preparatory to developing a removal plan. The plan will be coordinated with the appropriate Panels.

(4) The Board approved the Master Planning Schedule of the Board's activities as submitted by Mr. Williams on February 6, 1967.

(5) The Board approved the procedures for material testing and analysis. These procedures establish specific channels for all agencies involved in testing and analysis. Included in the channel were several check points to ensure the establishment of adequate control.

(6) A new Panel 21, Service Module Disposition, has been formed. This Panel will plan and execute the necessary Service Module activities. The Panel will obtain Board approval for the demating of the Command and Service Modules.

## **February 8, 1967**

(1) The Chairman reviewed and re-emphasized the Board's charter as amplified in a memorandum from Dr. Seamans dated February 3, 1967. In consonance with guidance contained therein, he also defined the relationship of the personnel supporting the Board, i.e., Representatives, Consultants, Liaison, Observers, the Secretariat and Panel Chairmen.

(2) The batteries used for reentry power were removed from the C/M after approval by the Board. There was no indication that these batteries contributed to the mishap.

(3) It was agreed that each system in the C/M would be removed individually, inspected and evaluated. However, each system will be removed only after it is conclusively determined it did not contribute to the source of ignition and is no longer required to evaluate interface with other systems and the Service Module.

(4) As a result of the interest shown by the Apollo 204 Review Board in the film, "Aircraft Wire Harness Fires," Manned Spacecraft Center (MSC) has been requested to conduct research on the phenomena shown in the film. The research will attempt to determine the validity of the wet wire phenomena as related to the type of wires used in the C/M when exposed to wide range of checkout and mission environments, including 100 per cent oxygen.

(5) Proposed Action Items 0053 through 0063 were presented and approved by the Board.

(6) It was brought up by Mr. C. Mathews that fairly heavy activity might take place in the area of testing systems and components as they are moved from the C/M to the plants of prime contractor and vendors. Discussion followed resulting in a requirement for the Board to determine who should accompany this material, i.e., representatives from NASA, NAA, subcontractors and/or an independent representative. An ad hoc committee was called to meet with Mr. Malley at 1:00 p.m. today to prepare a recommendation for the Board on this matter.

#### **February 9, 1967**

(1) A standardized diagram of various Apollo Command Module views was distributed for use by Panel members and for reference in the Final Report.

(2) A method for controlled handling of accident material for testing, analysis, etc., was approved by the Board. This applies to tests at both Kennedy Space Center and material sent off-site.

(3) The Chairman of each Panel presented a briefing to the Board on Panel accomplishments, future plans and, in a few cases, specific findings.

(4) A detailed report on the initial assessment of structural damage of the Command Module was presented to the Review Board. This report was based upon a visual inspection only. A more complete assessment of structural damage is to be accomplished in conjunction with the removal of each system.

(5) Proposed Action Items 0064 through 0080 were presented and approved by the Board subject to certain clarifications.

#### **February 10, 1967**

(1) Dr. Seamans and staff members attended the meetings at KSC this date. Short presentations were made to them on plans for the Final Report, fire propagation, photographic control, data integration and medical analysis. These officials also visited the Pyrotechnic Installation Building (PIB) and other areas under the Review Board's jurisdiction.

(2) The Chairman advised that Panel reports will be signed by Panel Chairmen only. Board Monitors of Panels were requested to assume the responsibility for assuring minority views are given proper consideration. If serious differences are not resolved they are to be included in Panel reports for the Board's consideration.

(3) The Chairman emphasized to the Board Members who are Panel Monitors that copies of all Panel reports should be forwarded to the, Panel 18 Integration Analysis for coordination and integration.

(4) A report on the assessment of manning requirements to assure proper implementation of tasks and to meet present schedules was requested of Board Monitors for each Panel. This assessment is due Tuesday morning, February 14.

(5) Following the adjournment of the Board meeting, a film was shown of approximately 10 minutes duration depicting Flammability of Paraffin at zero g in 100% Oxygen.

(6) Proposed Action Items 0081 and 0084 through 0107 were considered by the Board and approved. Note: Numbers 0082 and 0083 were not used.

#### **February 11 and 12, 1967**

(1) No formal meetings of the Board were conducted. Investigation continued on C/M and on debris and components that had been removed to the PIB.

(2) Reviews of work progress were conducted individually by Board Members.

#### **February 13, 1967**

(1) A nine-minute film, recently completed at MSC on C/M 008, was shown. This film was the result of a photographic study of what could be seen through the hatch window by a TV monitor, with varying degrees of external and internal lighting. This film will be available for correlation with eye witness accounts.

(2) Dr. Thompson advised that a meeting of the Board and Deputy Administrator, NASA, has been scheduled for February 22, 1967. The meeting will be primarily concerned with interim reports of the Panels.

(3) Dr. Thompson requested the Office of Manned Space Flight, Marshall Space Flight Center, Kennedy Space Center and Manned Spacecraft Center to provide the Board a detailed description of their responsibilities and organizational relationships and alignment in the Apollo program. This information will be used to perform a review of the Apollo Program organization.

(4) Proposed Action Items 0108 through 0112 were considered and approved by the Board.

(5) Dr. Van Dolah was requested to prepare a report by February 15, 1967, on flame propagation, for submission to Dr. Seamans.

(6) A group of specially built tables have been placed in the main bay of the Pyrotechnic Installation Building. Items removed from C/M 012 are displayed on these tables to permit required inspections without handling.

(7) It was decided by the Board to have special studies of the space suits conducted by the manufacturer and Manned Spacecraft Center's Crew Systems Division. This would enable the Board to obtain expert opinions regarding possible contributing factors to the accident and to gain information regarding future space suit design.

(8) Dr. Thompson reported that seven people from Marshall Space Flight Center and one person from Langley Research Center had arrived to support various Panels.

#### **February 14, 1967**

(1) The Chairman read excerpts from the report of the "Apollo Accident Hearing Before the Committee on Aeronautical and Space Sciences, United States Senate, Ninetieth Congress, February 7, 1967." He emphasized the importance being given this review by that Committee and the responsibility of the Board to respond promptly and completely to the Administrator.

(2) Selected Board Members and Panel Chairmen were instructed to prepare an interim report on actions to date with significant information and tentative findings. The Board will conduct a critique of the material to be presented on February 19, 1967. On February 22, 1967, the interim report will be presented to Dr. Seamans. The content and order of this briefing will be: (a) Board Organization and Investigation Techniques, Colonel Strang; (b) Description and Course of Fire, Mr. Pinkel; (c) Background, Mr. White; (d) Analysis and Tests in Pursuit of Cause, Dr. Faget; (e) Tentative Findings and Preliminary Recommendations, Colonel Borman.

(3) Dr. Van Dolah presented a report on the propagation of fire and tentative findings of Panel 5 for submission to Dr. Seamans.

(4) The removal of systems from the C/M has progressed satisfactorily. As a result, the C/M is scheduled to be removed from the Launch Vehicle on Friday, February 17, 1967. This action coincides

with the Master Planning Schedule developed by the Review Board on February 7, 1967.

- (5) Proposed Action Items 0113 through 0117 were considered and approved by the Board.

#### **February 15, 1967**

(1) Dr. Thompson received a letter dated February 10, 1967 from Dr. Seamans. The letter emphasized the importance of the investigation and transmitted copies of four letters from Senator Anderson to the Administrator, NASA, concerning the investigation. In essence, these letters state that the Senate Committee expects to be advised on a recurring basis as to the findings of Apollo Review Board.

(2) The Board received a detailed briefing on the recorded anomalies prior to and during the accident. These anomalies were transmitted by the C/M telemetry system to several recording stations. The principle anomalies were:

- a. Communication difficulties
- b. High flow rate in oxygen system
- c. Disruption of alternating current
- d. Telemetry readings from a disconnected gas chromatograph connector
- e. Change in gimbal angle of the inertial measurement unit which may indicate movement in the C/M

At the conclusion of this briefing, direction was given to conduct further analyses and testing in an effort to obtain specific conclusions.

- (3) A briefing and written report on Astro - Communication Circuits was presented to the Board.

#### **February 16, 1967**

(1) The task of removing the Command Module from the Space Vehicle was approved by the Board. Extensive photograph (motion and still) of this task was accomplished for review by the Board and possible release to the Press.

(2) Colonel Borman suggested the work schedule be reduced to a 2-shift, 6-day week, rather than the 3-shift, 7-day week, which has been in effect since the accident on January 27, 1967. This suggestion was approved and will be implemented after the C/M is positioned in the bonded area of the Pyrotechnic Installation Building (PIB) on February 17, 1967.

- (3) Proposed Action Items 0118 through 0144 were considered and approved by the Board.

#### **February 17, 1967**

- (1) Proposed Action Items 0145 through 0147 were considered and approved by the Board.

(2) The Board met with the Panel Chairmen to review the Panel preliminary reports. These reports will be used as a basis for preparation of the briefing for Dr. Seamans, February 22, 1967.

(3) Material Release Record Items 0001 through 0056 have been considered and approved by the Board. This system provides a formal and controlled means of releasing for normal program use various hardware, software, spares, tools and expendable supplies that were impounded at the time of the accident



and have been determined not to be related to the accident.

(4) The Command Module was separated from the Service Module and moved to the PIB where dis-assembly and investigation will continue.

#### **February 18, 1967**

(1) To clarify the content of the interim report briefing for Dr. Seamans, Colonel Strang presented an outline to the Board for approval. The outline was approved.

(2) In addition to the briefing for Dr. Seamans on February 22, 1967, the interim report briefing will be presented on February 21, 1967 to Dr. Mueller and his staff. Both briefings will be given at Kennedy Space Center.

(3) Panel summary reports were distributed to Board Members and Panel Chairmen. Dr. Thompson cautioned on the distribution control of these reports.

(4) Proposed Action Items 0148 and 0149 were considered and approved by the Board.

#### **February 19, 1967**

(1) The Board met to further develop the briefing for Dr. Seamans. Each speaker made an initial presentation using visual aids. Additions and corrections were discussed.

#### **February 20, 1967**

(1) The Board approved a plan for removing the Service Module from the Launch Vehicle. The actual removal was scheduled for February 21, 1967, whereupon the Service Module will be transported to the Manned Spacecraft Operations Building at KSC for detailed examination and testing.

(2) Dr. Thompson directed that a plan be developed to release Launch Complex 34 to Kennedy Space Center for normal use, following removal of the Service Module.

(3) Proposed Action Items 0150 and 0151 were considered and approved by the Board.

(4) Preparations are being made to remove the heat shield from the Command Module so that the floor of the Command Module can be inspected from the lower side.

#### **February 21, 1967**

(1) A briefing on the significant information, tentative findings and preliminary recommendations as developed by the Apollo 204 Review Board, was presented to Apollo Program officials by Board Members. The officials attending this briefing included: Dr. George E. Mueller, NASA, Washington, D. C., Dr. Kurt H. Debus, KSC, Dr. Robert R. Gilruth, MSC, Dr. Wernher Von Braun, MSFC, Major General Samuel C. Phillips, USAF, NASA, Washington, D. C., Brig. General C. H. Bolender, USAF, NASA, Washington, D. C., Lt. General Frank A. Bogart, USAF (Ret.), NASA, Washington, D. C., Major General Julian B. Bowman, USAF (Ret.), NASA, Washington, D. C., Mr. Christopher C. Kraft, Jr., MSC, Mr. George A. Low, MSC. These officials were accompanied by key staff personnel. In addition to the Board, Panel Chairmen and Representatives to the Board were in attendance. The briefing was a preview of that to be given to Dr. Seamans on February 22, 1967. The Apollo Program officials and their staffs were expressly invited by Dr. Thompson.

- (2) Proposed Action Item 0152 was considered and approved by the Board.
- (3) Material Release Record Items 0057 through 0072 were considered and approved by the Board.
- (4) Mr. Ashmun Brown, Office of Chief Counsel, KSC, was assigned to assist the Counsel to the Board.

#### **February 22, 1967**

(1) The formal briefing on the progress of the Apollo 204 Review Board was presented to Dr. Seamans. This briefing was generally similar to the one given on February 21, 1967 to Apollo Program officials, who were also in attendance on February 22, 1967. Additionally, Dr. Charles A. Berry (M. D.), Dr. Joseph F. Shea, Mr. Donald K. Slayton and Captain Walter H. Schirra, Jr., USN, of MSC; and Mr. David Williamson of Dr. Seamans' staff, attended the briefing.

(2) Dr. Thompson announced to the Board in general session that a survey showed some 1500 people were directly supporting the investigation. This number, which is considered quite conservative, included 600 personnel from the NASA, Air Force, Navy, Department of the Interior and other Government agencies; and 900 personnel from industry and universities.

(3) Proposed Action Items 0153 through 0157 were considered and approved by the Board.

(4) Material Release Record Items 0073 through 0103 were considered and approved by the Board.

#### **February 23, 1967**

(1) The Apollo Program officials, under the chairmanship of Dr. Mueller, briefed Dr. Seamans and the Apollo 204 Review Board. In attendance were those who received the Review Board briefing on February 22, 1967. The briefings included a status report of the Apollo Program, special tests being conducted or planned as a result of the accident and proposed actions relative to the tentative findings of the Review Board.

(2) Dr. Thompson, Colonel Borman and Dr. Van Dolah accompanied Dr. Seamans to Washington, D. C., to brief the Honorable James E. Webb, Administrator, NASA on the tentative findings and preliminary recommendations of the Board.

(3) Upon the departure of Dr. Thompson, Colonel Strang assumed the responsibilities of Acting Chairman. A plan was approved to consolidate three Panels into a single Panel. This consolidation of Panels 3, 16 and 18 will permit better utilization of personnel.

(4) The Spacecraft/Lunar Module Adapter (SLA) was removed from the Saturn Launch Vehicle and transported to the Manned Spacecraft Operations Building for investigation.

#### **February 24, 1967**

(1) Colonel Strang conducted a special meeting of the Board and Panel Chairmen to ascertain the status of each Panel's final report. He emphasized that the reports should be sufficiently detailed to enable the Board to arrive at sound, appropriate recommendations. He also stressed that findings should apply not only to proximate causes of accident, but to any deficiency that could adversely affect the Apollo Program.

(2) The Board approved the release of Launch Complex 34 through Level 4 to KSC for operations. The Board will continue to control access to Levels 5 through 8, (Material Release Record (MRR) Item 0123). MRR Items 0104 through 0122 were also approved.

(3) Dr. Thompson, Colonel Borman and Dr. Van Dolah met at NASA Headquarters with the Honorable James E. Webb, Administrator, and Dr. Seamans, to present the Apollo 204 Review Board interim findings.

(4) Proposed Action Items 0158 through 0162 were considered and approved by the Board.

#### **February 25, 1967**

1. Members of the Board visited the PIB to view the Environmental Control Unit removed from C/M 012.

2. Panel work plans and schedules for accomplishment of tasks and submission of final reports were reviewed by the Board. Dr. Thompson emphasized that Panel Chairmen will not be released from their responsibilities until the Board has formally accepted their respective reports. A memorandum to this effect will be sent all Panel Chairmen. Specific comment will be included requesting submission of final reports as soon as possible.

3. Following the Executive Session, Dr. Thompson, Colonel Borman, Dr. Faget, Dr. Van Dolah, Mr. Geer and Mr. White departed for their respective parent organizations. They are scheduled to return to KSC on February 28, 1967. During their absence, the Panels will continue to perform their investigation functions and Colonel Strang will be Acting Chairman of the Board as previously designated.

#### **February 26, 27, 28, 1967**

1. In the absence of Dr. Thompson and other Members of the Board, no formal meetings were conducted.

2. Panels continued to conduct their portions of the investigation. The disassembly of the Command Module and detailed analysis of components was accomplished as scheduled in the master plan. Several Panels initiated preparation of their final reports.

3. Proposed Action Item 0163, Service Module Investigation Plan, was approved by Col. Strang, due to its urgency, on February 27.

4. All Members of the Board, with the exception of Dr. Van Dolah, returned to KSC at approximately 6:30 p.m., February 28, 1967.

5. Initial visual inspection and X-ray analysis of the Environmental Control Unit was completed on February 28, 1967. The unit was moved from the PIB to the Life Support Building for disassembly and detailed analysis.

#### **March 1, 1967**

1. Dr. Thompson announced to the Board that a memorandum from Dr. Seamans, dated February 27, 1967, had been received designating the Director, Langley Research Center, the Custodian of Apollo 204 Review Board Material.

2. A general discussion was held (in Executive Session) regarding the future activities of the Panels and other Board activities, with the objective of developing assurance that the Board's Final Report will be completed by the end of March. An additional objective was to establish a mode of operation whereby the Board will be able to effect an orderly reduction of its activities at KSC, eventually re-

cess, and finally recommend to the Administrator that the Board be disbanded. Dr. Thompson remarked that certain tests and analyses which were stimulated by the Board's activities may more appropriately be of prime interest and concern to the Apollo Program Office. Such tests and analyses would not be followed in detail by the Board, however, the Board will require reports from the Program Office on the results so that the Final Report Appendix E, may include a statement of the results.

3. Dr. Faget presented a plan for the screening of removed equipment that is intended to reduce the amount of effort and time required to investigate and analyze equipment from Spacecraft 012. This plan was discussed by the Board and it was agreed that the Panel Coordination Committee establish an ad hoc group to perform the screening as proposed in the plan. The Panel Coordination Committee will report back to the Board on this activity.

4. Dr. Thompson announced that General Sessions would henceforth be held on Monday, Wednesday, and Friday of each week. Executive Sessions will continue on a daily schedule.

5. Proposed Action Items 0158 through 0162 and 0164 through 0167 were considered and approved by the Board. Item 0163 had previously been approved by Col. Strang.

6. Material Release Record Items 0127 through 0137 were considered and approved by the Board. Items 0124 through 0126 had previously been approved for release.

7. Following the Geners 1 Session, the Board viewed a film on fire propagation tests conducted at MSC in a boilerplate mock-up of the Command Module.

#### **March 2, 1967**

1. Proposed Action Items 0168 and 0169 were considered and approved by the Board.

2. Material Release Record Items 0138 through 0141 were considered and approved by the Board.

#### **March 3, 1967**

1. All material from the Command Module will be retained by the Board and will be designated Category A or B. Items in Category A are those that are damaged, or identified as suspect and/or associated with anomalies. Category B Items are those that appear to be absolved of association with the incident. They (Category B) will be eligible for use by the Apollo Program Office for nondestructive testing; however, the Board will require copies of all test reports. An Administrative Procedure will be released on this matter.

2. Col. Borman reported that the disassembly of the Command Module was expected to be complete by March 10, 1967. An around-the-clock work schedule was approved for the removal of the heat-shield.

3. The Board met with the Panel Chairmen to discuss final Panel report content and submission schedule. Tests that are not complete, when the Panel reports are submitted, will subsequently be integrated into the Final Board Report.

#### **March 4, 5, 1967**

1. Material Release Record Items 0142 through 0144, and 0146, were considered and approved by the Board. Item 0145 was held in abeyance pending further action.

2. Board Members reviewed transcripts and other material for inclusion in the Final Report.

### **March 6, 1967**

1. Mr. Mardel, Chairman, Panel 18, reported on an arc indication that was found on the Lower Equipment Bay junction box cover plate. A metallurgical analysis on the cover plate will be accomplished. Investigation will continue in an effort to identify and remove the wire that appears to have caused the arc.
2. Mr. Simpkinson, Chairman, Panel 4, presented a status report on the disassembly plan. Approval was granted by the Board to start removal of the heat-shield.
3. Proposed Action Items 0170 through 0177 were considered and approved by the Board.
4. Material Release Record Item 0147 was considered and approved by the Board.

### **March 7, 1967**

1. The aft heat shield was removed from C/M 012 in accordance with the master plan for disassembly. Close inspection of the C/M disclosed that the rupture in the floor extended approximately 2/3 around its circumference. This is much greater than originally estimated.
2. Material Release Record Items 0148 through 0150 were considered and approved by the Board.
3. The Board viewed a 30 minute film entitled "Apollo Mock-up Flame Propagation, Test No. 2". The Test was conducted in a biolerplate Apollo mock-up at MSC on March 4, 1967. The Board concluded that this was a valid test procedure for assessment of flame propagation, and to qualify materials for use in the spacecraft.
4. A general discussion was held on the subject of subsystem and component design as related to the ability to ensure that such hardware may be installed and subsequently maintained in a manner consistent with established quality control procedures.

### **March 8, 1967**

1. Dr. Faget gave a follow-up report on analysis of the arc indication on the Lower Equipment Bay junction box cover plate. The plate has been delivered to KSC Material Analysis Laboratory. In addition to the analysis of the arc indication, analysis will also be made of molten material found on the bottom of the plate.
2. Col. Strang briefed the Board on a proposed procedure for screening and processing final Panel Reports. Initial review and editing will be accomplished by Final Board Report Panel 17. After preliminary editing, the reports will be amended as necessary and distributed to each Board Member and Counsel for review. Panel Chairmen will then meet with the Board for oral erview, critique and acceptance of the report, or additional actions as necessary. The procedure was accepted by the Board.
3. A progress report on status of test analysis was presented to the Board. A total of 104 tests have been identified of which 45 have been closed and 59 remain in the open category.
4. Proposed Action Item 0178 was considered by the Board and approved.

### **March 9, 1967**

1. It was announced that the Crew Heat Shield had been removed from the Command Module, and that a total of 891 items have been removed to date.

2. Proposed Action Item 0179 was considered and approved by the Board.
3. Material Release Record Items 0151 through 0154 were considered and approved by the Board.
4. Dr. Faget suggested construction of a simple fixture, in the configuration of the Command Module, upon which the wire harnesses and bundles removed from C/M 012 can be placed for subsequent inspection. The study of this or other approaches to implement a detailed inspection of the harnesses was recommended by Dr. Faget. The Board approved this recommendation.
5. The Board appointed Mr. Robert Bruce, Langley Research Center, as an alternate Board designated agent for the Environmental Control System (ECS) investigation.

**March 10, 1967**

1. A report from the Screening Committee was made by Mr. Sassee. An assessment of activity of the Committee and a written report were requested for the General Session on March 15, 1967. The crew compartment and the aft heat shields have been removed from the C/M and reclassified to Category B in order to remove the requirement for a special 24-hour guard.
2. Colonel Borman presented the Disassembly report. Command Module (C/M) disassembly activities are now scheduled to be completed by March 18.
3. A film on Fire Propagation Test 3 conducted in the boilerplate mock-up at Manned Spacecraft Center (MSC) was shown. The C/M was simulated in Flight Configuration.
4. The Board met with Mr. L. Barnett of Panel 13 to conduct a critical review of that Panel's draft final report. The Board's comment were noted by Mr. Barnett and corrective and/or amplifying statements will be incorporated in the report.
5. Proposed Material Release Record Items 0155 and 0156 were presented for the Board's consideration and approved.

**March 11, 12, 1967**

1. Colonel Strang reported that Panels, 2, 12, 13, 16, 19 and 20 have submitted Final Reports. These six reports have been distributed to the Board Members for review.
2. Formal Board sessions were not held on March 11 and 12, 1967. The Board Members devoted their time to study of the final reports from six Panels. Disassembly and analysis continued as scheduled.

**March 13, 1967**

1. Board Members and Panel Members who received copies of witness statements in connection with their responsibilities were requested to return all copies to Panel 12 when this material is no longer needed.
2. A progress report on dismantling the Environmental Control Unit (ECU) was made to the Board by Mr. Williams. He also presented a proposed modification to Action Item 0153, Command Module Equipment Removal Plan. Following discussion by the Board, this modification was approved.
3. Mr. Robert Allnutt of NASA Headquarters was introduced by Mr. Malley. Mr. Allnutt, with Mr. Ashmun Brown, KSC Legal Staff, will assist Mr. Malley in the legal review of the Panel Reports and the Final Board Report.

4. The Board met with the following Panel Chairmen to conduct a critical review of their draft final report: Capt. J. Lovell, Panel 20; N. Vaughn, Panel 12; J. Atkins, Panel 19; G. Stoops, Panel 16. Each of the reports was accepted subject to editorial corrections.

5. The Board discussed reviews of Panel draft reports not yet received. Colonel Strang reported Panel 15, Final Report, will be available for review on March 13. The Board scheduled a meeting with Panel 5 on March 14. Further scheduling of meetings with Panels will be accomplished as reports are available.

#### **March 14, 1967**

1. Dr. Thompson advised that Dr. Gilruth and certain members of his staff will be at KSC on March 20 for the purpose of making a presentation to the Board on the subject of solder joints.

2. Colonel Borman presented the modified Panel 13 report for acceptance. The Board agreed with the report as modified and requested distribution to the Board Members for a final review.

3. Material Release Record Item 0161 was presented for the Board's consideration and approved. Items 0157, 0158, 0159 and 0160 were approved by Mr. Geer on March 13.

4. The Board met with Panel 21, Service Module Disposition, to review the final Panel Report. The Report was accepted subject to correction.

#### **March 15, 1967**

1. Disassembly of the ECU was completed this date.

2. The Board met with the Chairmen of Panels 5 and 6 for a preliminary review of their final reports.

3. Mr. Eldon E. Mathauser and Mr. Andrew G. Swanson, Langley Research Center, and Mr. Richard B. Ferguson, Manned Spacecraft Center, were appointed by Dr. Thompson to support the Board in the capacity of technically reviewing Final Panel Reports.

#### **March 16, 1967**

1. The Final Report from Panel 15, Administrative Procedures, was submitted to the Apollo 204 Review Board for individual study by Board members. In a special session the Board accepted the Final Report of Panel 15, subject to editorial corrections.

2. The Board met with Dr. Charles A. Berry (Chief, Division of Medical Research and Operations, MSC), Dr. Kelly, and Dr. Harter for a briefing on the life sciences portion of the Apollo 204 Review including the proposed final report of Panel 11, Medical Analysis. In addition to the Board Members, Mr. Malley, Counsel to the Board and Mr. Robert F. Allnutt, Assistant to the Counsel, were in attendance.

#### **March 17, 1967**

1. During the General Session, discussion was conducted by Dr. Thompson with the Panel Chairmen on preparation of their Final Reports and responsibilities of the Apollo 204 Review Board.

2. Mr. Simpkinson, Chairman of Panel 4, Disassembly Activities, reported on the status of C/M Disassembly. It is now scheduled for completion by March 22, 1967.

3. Colonel Borman presented MRR Items 0162 - 0166 which were approved.
4. Mr. Sasseen gave an interim report for the Screening Committee. Their report is expected to be completed by March 24, 1967.
5. Mr. Williams presented proposed Action Item 0180, which was considered and approved.
6. The Board met with the Chairman of Panel 8, Materials Review, to review the Final Panel Report. It was suggested that one additional test be accomplished, and reviewed by the Board prior to acceptance by the Board.
7. Colonel Strang discussed the selection of photographs for inclusion in the Panel reports and the Final Board Report. The photographs selected thus far were made available for review by the Board.
8. Mr. Simpkinson was appointed Special Assistant to the Board for technical matters pertaining to preparation of the Final Report.

**March 18, 19, 1967**

1. The Board met with the Chairmen of Panel 1, S/C and GSE Configuration; Panel 5, Origin and Propagation of Fire; Panel 10, Analysis of Fracture Areas; and Panel 14, Security of Operations, to review their Final Panel Reports. The reports were accepted subject to correction.
2. Material Release Record Items 0167 - 0192 were approved by the Board.

**March 20, 1967**

1. Col. Strang presented a progress report on the Final Panel Reports. As of March 19, 1967, Reports from the following Panels have been received and accepted by the Board, subject to editorial corrections: Panels 1, 8, 10, 12, 13, 14, 15, 16, 17, 19, 20 and 21. The Board accepted, subject to editorial correction, the findings and determinations of Panel 5.
2. The Deputy Administrator, NASA, designated Langley Research Center as the custodian of all materials dealing with the investigation and review of the Apollo 204 Accident. The Chairman of the Board, who has the responsibility of determining the materials that are to be included in the final repository, has determined that the following categories of materials are to be preserved:
  1. Reports, files, and working materials.
  2. Medical reports.
  3. Spacecraft 012 Command Module, its systems, components, and related drawings.Category 1 will be stored at Langley Research Center, Category 2 at Manned Spacecraft Center and Category 3 at Kennedy Space Center.

As long as the materials are under the jurisdiction of the Board, access to materials shall be in accordance with the Board's policy. When the Langley Research Center assumes custody of the materials, access will be in accordance with the policy established by the Director, Langley Research Center.

3. Dr. Van Dolah reported on a test being made in C/M 014 to attempt to determine the amount of static electricity that may be generated by a suited crewman.
4. Mr. Williams presented proposed Action Items 0181 and 0182. Explanatory comments were made by Dr. Van Dolah on Item 0181. Mr. Sasseen made distribution of a memorandum, subject: "Plan of Action for AC Inverter 2" relative to Action Item 0182. Both of these Action Items were approved by the Board.



5. Colonel Borman presented MRR Item #0193 for consideration. This item was approved by the Board.
6. Prior to the Executive Session, the Board met with Dr. Robert R. Gilruth, Director, MSC, and members of his staff, plus management and engineering personnel from North American Aviation, Inc. for a presentation on the subject of solder joints in the Command Module.

#### **March 21, 1967**

1. The Board reviewed and accepted, subjected to editorial correction, the Panel 4 Final Report. The Final Reports from Panels 7 and 11 were submitted to the Board for review.
2. The Board Chairman appointed Mr. F. E. Eastman (MSC) as the Board's agent to witness activities associated with removal, transportation, disassembly, and testing of the Static Inverter 2, S/N 09240 ML 0088, in accordance with Apollo Spacecraft Hardware Utilization Request 012503 dated March 21, 1967.
3. MRR Items 0194-0199 were presented for consideration and approved by the Board.

#### **March 22, 1967**

1. The Apollo 204 Review Board witnessed a demonstration on the removal of C/M crew hatches. The demonstration was conducted in the PIB using a mock-up C/M. The purpose of the demonstration was to provide the Review Board a thorough understanding of hatch removal both from the inside and outside of the C/M. Following this demonstration the Board went to the ACE Control Room (MSOB) to get first-hand knowledge of the operations that are carried out there.
2. Major Butler, in Colonel Strang's absence, presented a progress report on the Final Panel Reports. As of March 21, 1967, the Board has reviewed and accepted, subject to editorial corrections, the Final Reports of Panels 4, 5, and 11. The Final Reports from Panels 15, 16, 17, 19 and 21 have been submitted for printers copies. The Final Reports from Panels 10, 13, 14 and 20, presently being edited, are scheduled for submittal to the printers by early March 23.
3. Dr. Faget distributed a report on the updated status of the analysis of items under investigation by Panel 18. To date there are 105 items; 27 remain open and 78 are closed. None of the closed items fall into the category, "May have caused the accident."

#### **March 23, 1967**

1. The Board met with the Chairman and Members of Panel 7 to review the Panel's Final Report. The Report was returned for further action prior to acceptance.

#### **March 24, 1967**

1. The Board met with Panels 9 and 6 to review their Final Reports. These meetings required the full day, therefore, the General Session which had been scheduled for 10:30 a.m. was postponed.
2. MRR Item 0200 was considered by the Board and approved.
3. The Board will recess at 1:30 p.m., March 25 until 8:00 a.m., March 28. Regular activity of the Board will be discontinued during that period; however, Panel Report preparation and detailed testing and analysis will continue.

### **March 25, 1967**

1. The Board met with the Chairman and Members of Panel 18 for a brief preliminary review of their Report. The Board also met with the Chairman and Members of Panel 2 to review that Panel's Final Report. The Report was accepted, subjected to incorporation of corrections and amplifying statements.
2. The Board reported that all Panel Reports have been reviewed. A second review of the Reports from Panels 5, 9 and 18 will be accomplished next week.
3. The Board recessed until 8:00 a.m., March 28.

### **March 28, 1967**

1. The Board was in recess from March 25 at 1:00 p.m. until March 28 at 8:00 a.m., however, work continued in the preparation of Panel Reports.
2. Colonel Strang made the following report on the progress and preparation of the Final Reports:  
A follow-on review by the Board of Final Reports from Panels 3, 5, 7, 9, 12 and 18 is required. The Panel 18 Report will be available for Board review at 8:00 a.m., March 29. The Board scheduled a meeting with Panel 18 for 1:00 p.m., March 29 to conduct a critical review of their Report. It is tentatively planned that the Board will review Final Reports with Panels 7 and 9 on March 30. Reviews with Panels 3, 5 and 12 will also be scheduled.  
Eleven Panel Reports have been submitted for varityping. Final Reports from Panels 4, 10, 14, 16, 17, 19 and 21 plus Parts I and II of the Final Report and General Session Minutes were distributed by Col. Strang. This material is to be reviewed by the Board Members and Counsel prior to printing of the Final Report.  
Specific assignments have been made regarding preparation of a narrative describing the Spacecraft 012 test sequences and their objectives, the time line of events from start of the T-10 hold through medical determination of death and the investigation and analysis activities of the Board.
3. Mr. Malley discussed preparation of findings, determinations and recommendations. He also stated that if corrections are made after varityping, they can be included in the Final Report as Addenda and Corrigenda.
4. Dr. Thompson asked for a report on PIB activity. Colonel Borman introduced MRR Items 0201, 0202 and 0203 which were considered by the Board and approved. Disassembly of the Spacecraft was completed on March 27 during the first shift. 1241 items are logged in as having gone through the Bond Room for display to Review Board and Panel personnel. Of these, approximately 1000 came from the C/M.
5. The Final Report of the Screening Committee was distributed by Mr. Sasseen to the Board Members for their review. Mr. Sasseen stated that the following eight items will be retained in Category A:
  - Lower Equipment Bay Junction Box Cover Plate
  - Command Pilot's Torso Harness
  - Velcro and Raschel Netting
  - Static Inverter 2
  - Main Display Control Panel 8
  - Instrumentation Data Distribution Panel J800/J850
  - Octopus Cable
6. Dr. Faget advised that LiOH cartridge has been sent to MSC for analysis. Mr. Callahan of OMSF was appointed courier to handcarry this Item to MSC. Mr. R. S. Johnston has been designated the Board's witness for the analysis. MSC's Crew Systems Laboratory will perform the analysis and provide

the Board with a report. Objective of the analysis will be to identify contaminants in the LiOH and to determine the quantity of CO<sub>2</sub> in the LiOH.

7. Members of the Board and other interested personnel viewed a demonstration in the Spacecraft Mock-up at the PIB of hatch removal conducted by NAA personnel who performed this function at the time of the accident.

8. Mr. William D. Mangan, LaRC, Office of the Chief Counsel, joined the Legal Staff supporting the Board.

#### **March 29, 1967**

1. The Board Members met with Panel 18 to conduct a critical review of the Panel 18 Report.

2. Colonel Strang reviewed the status of Final Report preparation. The Board scheduled a review meeting with Panel 9 for March 20 at 9:00 a.m., to be followed by meetings with Panels 7, 6 and 3, as time permits. The reports from Panels 11 and 12 are being clarified in certain places prior to re-typing.

#### **March 30, 1967**

1. The Board met with the Chairmen and Members of Panels 9, 7 and 3, to complete acceptance of their Final Panel Reports.

#### **March 31, 1967**

1. Col. Strang made the following report on the status of Final Panel Reports:

Reports from the following Panels have had printer's copies prepared and distributed to the Board for final review: 4, 10, 14, 16, 17 and 21. Most of these reports have been returned by Board Members for final editing and printing.

The following Panel Reports are being processed today for preparation of printer's copies: 3, 5, 7, 11 and 6.

Printer's copies of Panel Reports 1, 13, 15 and 20 are to be distributed to the Board today for final review.

Final draft copies of Panel Reports 2, 8, 7 and 12 are being reviewed by Board Members. After return of these reports to Panel 17, they will be processed for preparation of printer's copies and subsequently distributed to the Board for final review.

The Final Report from Panel 18 is still undergoing rewrite by the Panel.

2. Col. Borman introduced MRR 0204 to release the complete Launch Escape System from Category A to C. He requested approval for a general MRR to release from Category A to C all parts and equipment that were not attached to the Spacecraft at the time of the accident. Approval was granted on both of these items.

4. The Final Report of the Screening Committee was distributed by Mr. Sasseen at the General Session for Board review. The Board approved the categorizing of the parts, components and assemblies of the Spacecraft. Dr. Thompson stated that the Board accepts the report as the basis on which the handling of these parts, components and assemblies will be followed regarding custody and access to them.

5. Mr. William E. Guilian, Chief Counsel, Marshall Space Flight Center, has joined the Legal Staff supporting the Board.

6. Dr. Thompson announced that in view of the imminent completion of the Investigation and Final Report, the March 31 General Session would be the last scheduled meeting of the Board. Any subsequent meetings which may be required prior to the time the Board is recessed at the completion of the Final Report will be called by the Chairman.



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
WASHINGTON, D.C. 20546

February 27, 1967

OFFICE OF THE ADMINISTRATOR

MEMORANDUM

To: Chairman, Apollo 204 Review Board

From: Robert C. Seamans, Jr.  
Deputy Administrator

Subject: Custody of Apollo 204 Review Board materials

The Langley Research Center, Hampton, Virginia, is designated as the custodian of all pertinent physical evidence, reports, files, and working materials dealing with the investigations and review of the Apollo 204 accident.

The Director, Langley Research Center, shall assure that adequate secure storage and warehousing is made available at appropriate locations for this purpose. These materials will be in the final custody of the Director, and access thereto shall be determined by him or by the general counsel at the Center as his designee.

The Chairman of the Board shall determine the materials that are to be included in the final repository and shall arrange for the most useful disposition of the remaining materials not selected for final retention.

A handwritten signature in dark ink, appearing to read "Robert C. Seamans, Jr.", is positioned above the typed name.

Robert C. Seamans, Jr.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

NOV 1 1967

IN REPLY REFER TO

TO : Director, Langley Research Center  
FROM : Chairman, Apollo 204 Review Board  
SUBJECT: Custody of Apollo 204 Review Board Materials

By memorandum dated February 27, 1967, Enclosure 1, the Deputy Administrator designated Langley Research Center as the custodian of all materials dealing with the investigations and review of the Apollo 204 accident. The materials are divided into three categories:

1. Reports, files and working materials
2. Medical reports
3. Spacecraft 012, its systems and components

Category 1 will be stored at Langley Research Center; Category 2 at Manned Spacecraft Center; and Category 3 at Kennedy Space Center. Custodial agents have been designated at the three Centers, Enclosures 2, 3 and 4. Administrative Procedure 23A, Enclosure 5, sets out the procedure for custodial agents to follow.

It will be the responsibility of the Director, Langley Research Center to provide suitable secure storage space for the materials, to insure that an index file is established for location of materials, and, at the appropriate time, to transfer custody and storage of the materials in accordance with regulations of the Administrator, General Services Administration.

The provisions of Title 44 U. S. C. § 396 and NMI 1440.1 are applicable.

  
Dr. Floyd L. Thompson

Enclosures  
As Stated

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 1, 1967

TO: Assistant Chief, Administrative Services Division  
Langley Research Center

FROM: Chairman, Apollo 204 Review Board


SUBJECT: Designation of Custodial Agent

By memorandum dated February 27, 1967, Enclosure 1, the Deputy Administrator designated Langley Research Center as the custodian of all materials dealing with the investigations and review of the Apollo 204 accident. The Chairman of the Board, having the responsibility of determining the materials that are to be included in the final repository, has determined that the following categories of materials are to be preserved:

1. Reports, files and working materials
2. Medical reports
3. Spacecraft 012 Command Module, its systems, components and related drawings

Category 1 will be stored at Langley Research Center; Category 2 at Manned Spacecraft Center; and Category 3 at Kennedy Space Center.

You are designated Custodial Agent of Category 1. The policy and procedures set forth in Apollo 204 Review Board Procedures 5, 11 and 23A, appended as Enclosures 2, 3 and 4, are applicable.

  
Dr. Floyd L. Thompson

Enclosures  
as stated

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

March 1, 1967

IN REPLY REFER TO

TO: Manager, Apollo Spacecraft Program Office  
Manned Spacecraft Center

FROM: Chairman, Apollo 204 Review Board

SUBJECT: Designation of Custodial Agent

By memorandum dated February 27, 1967, Enclosure 1, the Deputy Administrator designated Langley Research Center as the custodian of all materials dealing with the investigations and review of the Apollo 204 accident. The Chairman of the Board, having the responsibility of determining the materials that are to be included in the final repository, has determined that the following categories of materials are to be preserved:

1. Reports, files and working materials
2. Medical reports
3. Spacecraft 012 Command Module, its systems, components and related drawings

Category 1 will be stored at Langley Research Center; Category 2 at Manned Spacecraft Center; and Category 3 at Kennedy Space Center.

You are designated Custodial Agent of Category 3. The policy and procedures set forth in Apollo 204 Review Board Procedures 5, 11 and 23A, appended as Enclosures 2, 3 and 4, are applicable.

This delegation of authority is made with the power of redelegation to a member of the Spacecraft Program Office.

  
Dr. Floyd L. Thompson

Enclosures  
as stated

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

TO: Director, Kennedy Space Center

MAR 20 1967

FROM: Chairman, Apollo 204 Review Board

SUBJECT: Custody of Apollo 204 Review Board Materials

By memorandum dated February 27, 1967, Enclosure 1, the Deputy Administrator designated Langley Research Center as the custodian of all materials dealing with the investigations and review of the Apollo 204 accident. The materials are divided into three categories:

1. Reports, files, and working materials
2. Medical reports
3. Spacecraft 012 Command Module, its systems, components, and related drawings.

Category 1 will be stored at Langley Research Center; Category 2 at Manned Spacecraft Center; and Category 3 at Kennedy Space Center. Custodial agents have been designated for each category, Enclosures 2, 3, and 4. Administrative Procedure 23A, Enclosure 5, sets out the procedure for custodial agents to follow.

The Director, KSC, is requested to provide suitable secure storage space for the Spacecraft 012 Command Module, its systems, components, and related drawings.

I would appreciate being advised of the nature and location of the proposed storage area at your earliest convenience.

  
Dr. Floyd L. Thompson

Enclosure: a/s

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

APOLLO 204 REVIEW BOARD

IN REPLY REFER TO

March 1, 1967

TO: Director of Medical Research and Operations  
Manned Spacecraft Center

FROM: Chairman, Apollo 204 Review Board

SUBJECT: Designation of Custodial Agent

By memorandum dated February 27, 1967, Enclosure 1, the Deputy Administrator designated Langley Research Center as the custodian of all materials dealing with the investigations and review of the Apollo 204 accident. The Chairman of the Board, having the responsibility of determining the materials that are to be included in the final repository, has determined that the following categories of materials are to be pre-served:

1. Reports, files and working materials
2. Medical reports
3. Spacecraft 012 Command Module, its systems, components and related drawings

Category 1 will be stored at Langley Research Center; Category 2 at Manned Spacecraft Center; and Category 3 at Kennedy Space Center.

You are designated Custodial Agent of Category 2. The policy and procedures set forth in Apollo 204 Review Board Procedures 5, 11 and 23A, appended at Enclosures 2, 3 and 4, are applicable.

This delegation of authority is made with the power of redelegation to a member of your staff.

  
Dr. Floyd L. Thompson

Enclosures  
as stated

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
WASHINGTON, D.C. 20546

OFFICE OF THE ADMINISTRATOR

February 3, 1967

MEMORANDUM

To: Mr. James E. Webb  
Administrator

From: Robert C. Seamans, Jr.  
Deputy Administrator

Subject: Report on Apollo 204 Review Board Discussions

I spent yesterday at the Kennedy Space Center with the Apollo Review Board and other key personnel involved in the current investigation of the causes and circumstances of the Apollo 204 accident.

First, there has been no determination of the specific cause of the fire that resulted in the deaths of Lt. Colonel Grissom, Lt. Colonel White, and Lt. Commander Chaffee. The retracing of possible, and then of probable, chains of events in such an accident is a complex task that is demanding the complete attention of the Review Board headed by Dr. Floyd Thompson, of the assistants and consultants to the Board, and of many of the elements of government, industry, and universities involved in the Apollo program.

The Board is taking full advantage of the extensive taped data available as well as records made prior to the accident, the present condition of the spacecraft, and the reports of those involved in the test. All the physical evidence and data concerned with the test were impounded immediately following the accident. This was to assure that no pertinent information would be lost and that no actions would be taken except in the full context of all the data available.

As I have stated, the preliminary review of this information has not provided any direct indication of the origin of the fire; the preliminary analyses point to the conclusion that a clear identification of the source of ignition or of its possible source will depend upon detailed step-by-step examination of the entire spacecraft and its related test support equipment.

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At present, the spacecraft is still mated to the unfueled launch vehicle at the pad. However, it is being prepared for removal to our industrial area where it will be disassembled and where experts in many technical and scientific areas can work with the physical evidence. Prior to disassembly of the damaged spacecraft, an undamaged and nearly identical (#014) spacecraft will be used to establish the conditions existing prior to the accident. The 014 spacecraft was flown from the North American plant in California to Cape Kennedy on February 1.

The current plans are to go through a parallel, step-by-step disassembly process, first working on the undamaged vehicle and then repeating as closely as possible the procedure on the damaged vehicle.

In addition to analyses of recorded and physical data and equipment, the Board is defining a series of investigative tasks and is assigning these to teams for execution. For example, a team is charged with the chemical and spectrographic analysis of damaged elements aimed at identifying the propagative history of the fire. Another is working on relating the propagation history to the flammability characteristics of the spacecraft materials. Another is dealing with design analyses and experimental tests to help establish possible ignition sources. As work progresses and a pattern of information emerges, additional tasks, analyses, and reviews will undoubtedly be instituted by the Board.

From information now available to the Board, I had an opportunity to learn more about certain specific aspects of the simulated mission and the test sequence itself than we had previously had before us in a clearly related pattern.

At 6:31:03 pm EST the fire was first detected. The mission was holding at T-10 minutes. Up to this time there had been only minor difficulties with the equipment. The purpose of the hold was to provide an opportunity to improve the communications between the spacecraft and the ground crew.

Up to this time the cabin pressure, the cabin temperature, and the oxygen suit supply temperature were nominal. The oxygen rate of flow into the suits had shown an increase 4 seconds prior to this time but we have not been able to relate this to the accident.

Lt. Col. White was the only astronaut instrumented for heart rate and respiration. His heart rate had shown an increase 40 seconds prior to this time, but at 6:31:03 his heart was at the normal level for him when in a relaxed prone position.

The spacecraft was operating on external power. Earlier in the day, at 9:30 a.m. EST, the system for transfer from external (ground) power to simulated internal (spacecraft) power had been tested, and operated normally. The fuel cells in the service module were not in use, and the so-called internal power was being supplied by batteries having the same characteristics as the fuel cells but located external to the spacecraft. If the accident had not occurred, the transfer from external to simulated internal power would have taken place on resumption of the count.

At the press conference on Saturday morning, Apollo Program Director S. C. Phillips was asked whether the spacecraft was on internal or external power when the fire occurred. At that time he did not realize that the spacecraft was still on external power since he had in mind primarily the eyewitness reports. Subsequent examination of the data has established the above power supply sequences. There is no evidence up to this time that the source of power whether simulated internal or external was related to the accident.

Lt. Colonel Grissom was the command pilot, sitting in the left seat; Lt. Colonel White, the senior pilot, sitting in the middle seat; and Lt. Commander Chaffee, the pilot, was in the right seat. In the event of emergency, the procedure is for the senior pilot (White) to reach high over his left shoulder to actuate the inner hatch release handle. The command pilot (Grissom), after lowering the center headrest, aids the senior pilot in lifting the inner hatch and removing it to the floor of the spacecraft. The main duty of the pilot (Chaffee) during this procedure is to maintain communication and assist in the removal of the inner hatch if needed. From the following data, you will note that the crew appeared to follow the correct procedure.

At 6:31:03, Pilot Chaffee reported that a fire existed in the spacecraft. At about this time Senior Pilot White's heart rate started to increase. At 6:31:04 the inertial platform in the capsule gave an indication of a small amount of motion which may have been caused by movement of the crew. At 6:31:05 the cabin temperature began to rise. At 6:31:09 Senior Pilot White repeated the previous report saying that there was a fire in the cockpit. At the same time the cabin pressure commenced to rise and a larger amount of motion was indicated by the inertial platform. This means that the crew were commencing their emergency egress procedure.

At 6:31:12, or nine seconds after the first indication of fire, the cabin temperature started to increase rapidly and pilot Chaffee reported that a bad fire existed in the cabin. Also at this time pilot Chaffee increased the illumination of the cabin lights and actuated the entry (internal) batteries. No other intelligible communications were received although some listeners believe there was one sharp cry of pain. Loss of radio signal occurred a few seconds later.

The oxygen supply to the astronaut suits, which had been holding nearly constant, pressure and temperature started to fluctuate at the time of signal loss. At 6:31:17 or fourteen seconds after the fire was first detected, the cabin pressure reached a level of approximately 29 psi and the cabin ruptured.

One and one-half minutes after the start of the fire, the ground power was switched off. Various command module systems continued to operate on the entry (internal) battery power until about 12:30 am EST on Saturday when the batteries ran down.

The official death certificates for all three crew members list the cause of death as asphyxiation due to smoke inhalation due to the fire.

I would like to emphasize that this report is based on preliminary information. This information has not as yet been extensively analyzed by the Apollo Review Board under Dr. Thompson. Since the data were recorded at a number of different stations, the time sequences may not be perfectly synchronized, possibly giving rise to errors of one or two seconds.

During my meetings with the Board a number of other items of information were discussed but I believe that the data I have outlined include all events having a significant bearing on an understanding of the accident.



Robert C. Seamans, Jr.



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
WASHINGTON, D.C. 20546

OFFICE OF THE ADMINISTRATOR

February 14, 1967

MEMORANDUM

To: Mr. James E. Webb  
Administrator

From: Robert C. Seamans, Jr.  
Deputy Administrator

Subject: Further report on Apollo 204 Review Board Activities

On February 10 I met with the Apollo 204 Review Board at KSC to discuss their progress in the investigation of the Apollo accident.

The Board now has 21 panels established and operating, each with a specific assigned task, each chaired by a Government employee, and each reporting to a specific Board member. A detailed Review Board activity schedule has been established and is reviewed daily to ensure that milestones are being met or that scheduled adjustments are made as early as necessary. This permits close coordination and integration of all the necessary activities, analyses, and studies.

In order to speed up the investigative effort, the Apollo 012 spacecraft is being mapped in detail, using a 3-dimensional coordinate system to which all physical spacecraft elements can be referred. Complete photographic coverage is being maintained, color film being preferred since it permits more ready identification of components and their condition. Each photograph is cross-referenced to the master grid.

The Board has implemented a data control system that permits a visual display, against a time-line background, of each step of the investigation. As spacecraft systems are examined and as their utilization in the 204 test is established, these are noted and color coded: at a glance, one can determine whether a system might have caused the accident or has proven to be non-contributory, and also whether a particular analysis is still underway or completed. This method of data control focuses on the critical areas requiring the greatest attention.

I reviewed at some length the work and procedures of the panel that is investigating the origin and propagation of the fire. While their work is far from complete, I am satisfied that the procedures they are following are well worked out. When this work is completed, it will give us as clear a view as can be obtained from the evidence. The panel has begun by examining each possible combustible within the spacecraft, its distribution and characteristics, and its proximity to each possible ignition source. Such combustibles include both solids and liquids. At each step of spacecraft disassembly, panel members are carefully removing both damaged and undamaged materials for micro-analysis which, in turn, permits the identification of the material that was burned. This allows a reconstruction of the final location of all combustibles in the spacecraft and will point up irregularities in this distribution if any exist. The physical evidence thus far examined points to the following:

First, it appears the fire had considerable variation and directionality, since damage in the spacecraft indicates differences of intensity and timing. For example, an aluminum tubing handle has a hole burned through it indicating a temperature at that point of at least 1,400° F, while its nylon hinge within two inches of the melted spot is relatively undamaged indicating a temperature there of less than 500° F.

Second, there is evidence that the fire may have had more than one phase, but this is difficult to prove since the last phase would obscure the evidence of the earlier. One hypothesis, supported by the cabin pressure history, assumes a small, low-grade fire whose heat was at first largely absorbed by the spacecraft structure and that was burning at the time of the first crew report; that fire may have continued for as long as ten seconds. A more intense fire may have then developed, causing the rapid increase in cabin pressure. This fire was probably then extinguished by the depletion of oxygen.

Other peculiarities require further analysis. These deal with the ruptures in the spacecraft and the role of the fire in burning through into the space between the inner and outer hulls.

At this time, there has been no determination as to the source of the ignition itself.

Additional information relating to the progress of the accident has been identified and is being analyzed. A recording from an onboard bio-sensor that appears relatively undamaged is in the process of being read out at this time. Additional work to interpret all background sounds on a high fidelity recording obtained over the S-band link is being carried out in the hope of gaining further information on the course of the fire. I also reviewed with the physician who heads the medical analysis panel the condition of the personal effects, suits, and equipment of the crew as well as data available on their actions during the course of the accident. It is now clear that all three suits were burned through, though the extent of suit damage varies; the command pilot's received the greatest exposure to flame and the pilot's the least.

Spacecraft disassembly is proceeding with great care; for example, a false floor with plexiglass viewing ports has been installed to permit continued examination without the danger of disturbing physical evidence. Current plans are for the final removal of the spacecraft to the industrial area by the end of this week. Detailed plans for the continued disassembly of both the command module and service module are in preparation and will be reviewed and approved by the Board before further work is undertaken. It is important to note that no single spacecraft element is touched or removed for analysis without full Board approval and evaluation of its possible effect on any of the other on-going studies or analyses.

Robert C. Seamans, Jr.

Robert C. Seamans, Jr.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
WASHINGTON, D.C. 20546

OFFICE OF THE ADMINISTRATOR

February 25, 1967

MEMORANDUM

To: Mr. James E. Webb  
Administrator

From: Dr. Robert C. Seamans, Jr.  
Deputy Administrator

Subject: Interim report of the Apollo 204 Review Board

On February 22, 1967, I heard a presentation by the Apollo 204 Review Board at Kennedy Space Center of the significant information developed to date and of their tentative findings concerning the circumstances of the accident. The Board also discussed preliminary recommendations. These tentative findings and preliminary recommendations will serve as guides for those interim decisions to be made in the conduct of the Apollo Program prior to the completion of the Board report. I also reviewed the status of the investigation and of spacecraft disassembly, and followed up on items previously noted in earlier reports.

The spacecraft has been removed from the launch vehicle and is now housed in the industrial area. There detailed disassembly continues under careful supervision, each action being undertaken in response to a specific Board directive. This disassembly is far from complete, but a number of the major systems have been removed and are being checked for further verification of the part they played during the fire, the effect of fire on the equipment, and the evidence that analysis might add to the overall picture being built up of the accident. The heat shield has not yet been removed, nor has sufficient internal equipment to permit full view from inside of the entire pressure hull, and a large number of tests, checks and analysis are continuing at NASA, university, and industrial facilities around the country. At present, the Board has over 1,500 individuals, from nine government agencies and departments in addition to NASA, from thirty-one industrial groups, and from several universities, directly participating in the review and analysis. The Board currently estimates that its report will be completed by the end of March. The Board is developing procedures to assure that an orderly and rapid transition of the personnel under its control from the current accident investigation to redesign, qualification, and test effort where required can be made.

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In my last report, I noted that an intact on-board biosensor recording was being analyzed for possible additional information; this analysis is now complete and provides a little more than one second's additional information and duplicates data already examined that was available from the telemetry recorded during the test and subsequent accident. The S-band recording also mentioned in the previous report has been completely analyzed by the Bell Laboratories, including computer reconstruction and comparison, but no significant new information could be derived therefrom.

The Board has not identified the source of ignition at this time. Ignition sources that have been under review include: possible chemical reactions, such as those in the on-board batteries or in the air purifier of the environmental control unit; possible spontaneous combustion of certain materials used in the spacecraft; and possible electrical phenomena, such as electro-static spark discharges, electrical arcing, or wiring overheating from shorts or malfunctions.

Examination of the environmental control unit lithium hydroxide and of the batteries indicates these were not the source of ignition. Tests of the combustible materials used in the spacecraft show that at least a 400°F temperature would be necessary for spontaneous combustion, and that no such materials could have been subjected to that temperature except by the malfunction of some other part of the spacecraft systems. An electrical malfunction is therefore regarded as the most likely source of ignition. While not wholly ruled out, electro-static discharge is deemed unlikely in that all reasonable concentrations of flammable vapors that could have been present in the spacecraft were not sensitive to this type of sparking ignition.

By the time it has completed its final report, the Board expects to have significantly narrowed the list of ignition sources that had a relatively high possibility of contributing to the initiation of the fire, but the possibility exists that no single source will ever be pinpointed.

A good deal of the work involved in tracing the history of the fire after ignition has been completed. The Board has considerable confidence in its present theory as to the initial location, propagation mechanisms, and phasing of the fire. This hypothesis, and some of the supporting evidence, is summarized as follows:

Present evidence indicates that the fire had three distinct phases. The fire originated in the left, or command pilot side, in the front corner of the spacecraft, near the floor. It probably burned for several seconds without being noticed by the crew or recorded on instrumentation. Because it was below the couch level it was not visible

at this stage; because the crew were fully suited and breathing oxygen from the environmental control system rather than from the cabin, it was not smelled or heard. The left front corner shows the evidence of highest heat and longest duration of the fire, and the witnesses watching the television monitors place the first appearance of flame in that corner (the television camera was mounted outside the spacecraft, looking in through the window in the hatch). The first crew report of fire was at 6:31:04, EST, indicating the fire had become visible. Because the metal structure of the spacecraft absorbed the initial heat, the fire did not initially cause an increase in cabin pressure.

By 6:31:12, the fire had spread and become intense, igniting various materials along the left side of the cabin. Flames were hot and smoke-free, rising along the wall and spreading across the ceiling. The cabin shows heavy damage in this area but little smoke, indicating that the oxygen in the cabin had not been depleted at this time. The fire spread and fed on nylon netting (installed to prevent objects from floating into equipment crevices while in zero-g), Velcro fastening material (used to fasten equipment to the spacecraft interior), and the environmental control unit insulation. The cabin pressure began to rise rapidly at this time as the atmosphere became heated.

At approximately 6:31:19, the internal pressure had risen to an estimated 36 pounds per square inch and the sealed cabin ruptured. This first puncture of the pressure vessel was a long tear in the floor on the right, or pilot's, side of the cabin. With the high internal pressure released, cabin gases and flames flowed both over and under the couches toward and through the hole, moving from left to right. This was the second phase of the fire. Flames passed through the hole into the air space between the cabin pressure shell and the surrounding heat shield; these flames then escaped through access hatches in the heat shield and partially enveloped the outside of the spacecraft for a moment. The short duration, left-to-right, flame motion is evidenced by heavier damage on the left than right side of equipment and wiring on the floor, of the couches, and of the front panels.

With the rupture of the cabin and the rush of flame and gas outside, the oxygen content of the cabin atmosphere was quickly reduced and the fire smoked heavily, laying a film of soot on many interior surfaces. This third and final phase of the fire was also characterized by continued localized burning. The environmental control system uses a water/glycol coolant that leaked from burnt or burst pipes. Both high and low pressure oxygen lines were connected with solder joints that fail at temperatures below 400°F. The glycol mixture from the cooling system, acting as a fuel and supported by the flowing oxygen from the failed lines, caused continued hot burning in the left corner and melted a large hole in the floor there.

The Board noted that the underlying design approach in Apollo was to control the known risk of fire--on the pad or in orbit--by isolating and rendering safe all possible ignition sources. The experience in flight and in tests prior to the accident had suggested that the probability of a spacecraft fire was low. Continued alertness to the possibility of fire had become dulled by previous ground experience and six years of successful manned missions. Ground tests at the pad were classified as especially hazardous only when propellants or pyrotechnics were involved, and different procedures and safety precautions are taken in handling or working under such conditions. Potential ignition sources inside the spacecraft had been treated so as to be considered safe; neither the crews nor the test and development personnel felt the risk of spacecraft fire to be high. The Apollo 204 accident now proves this assumption to have been wrong.

The assumption of ignition source safety led to the use of several solid combustible materials within the spacecraft, including nylon and polyurethane foams. From the point of view of possible fire, these materials were distributed within the cabin without breaks specifically designed to help localize fire if it occurred.

The Board noted that, in the event of a fire emergency, the time and effort required to open the hatch was too long, and that pad emergency procedures were focused on propellant hazards and did not include provisions to meet spacecraft fires.

The principal preliminary recommendations of the Board are designed to assist the Administrator in making his decisions concerning the continuing Apollo program effort prior to completion of the Board review. These are:

That combustible materials now used be replaced wherever possible with non-flammable materials, that non-metallic materials that are used be arranged to maintain fire breaks, that systems for oxygen or liquid combustibles be made fire resistant, and that full flammability tests be conducted with a mockup of the new configuration.

That a more rapidly and more easily operated hatch be designed and installed.

That on-the-pad emergency procedures be revised to recognize the possibility of cabin fire.

In addition, the Board has drawn attention to a number of components, subsystems, techniques, and practices which it feels can be improved to increase crew safety and mission reliability. These include findings on the environmental control system solder joints, location of wiring, electrical equipment qualification and design, and the development of checkout procedures.

An important area of Board attention has been that of the cabin atmosphere. The atmosphere and pressure selected for the suit and the cabin, before launch and in orbit, have a very important relation to spacecraft design, hatch type, crew physiology, launch procedures, and mission capability. The Board did not recommend a change in the use of pure oxygen in the suit for either pre-launch or orbital operations. The Board did not recommend that cabin atmosphere for operations in space be changed from the currently planned 5 psi pure oxygen but did recommend that the trade-offs between one- and two-gas atmospheres be re-evaluated. The Board specifically recommended that pressurized oxygen no longer be used in pre-launch operations.

A handwritten signature in dark ink, reading "Robert C. Seamans, Jr." with a stylized flourish at the end.

Robert C. Seamans, Jr.

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# NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON, D.C. 20546

OFFICE OF THE ADMINISTRATOR

February 25, 1967

## STATEMENT BY

JAMES E. WEBB

NASA is releasing today a third interim report on the work of the Apollo 204 Review Board resulting from two days of meetings with the Board by Deputy Administrator Robert Seamans at Cape Kennedy. These meetings took place on February 23 and 24.

This statement and Dr. Seamans' third interim report have been reviewed with Chairman Clinton Anderson and Senior Minority Committee Member Senator Margaret Chase Smith and with Congressman George Miller. In continuation of the Senate Committee's review of the Apollo 204 accident, Senator Anderson has announced that the Senate Committee will hold an open hearing on the preliminary findings of the Board and actions to be taken by NASA at 3 p.m., Monday, February 27.

In addition to the information set forth by Dr. Seamans in his three interim reports, I have had the benefit of a review by three members of the Board -- the Chairman, Dr. Floyd Thompson, Astronaut Frank Borman, and Department of Interior combustion expert Dr. Robert Van Dolah. This included the preliminary views of the Board as to the most likely causes of ignition, the contributing factors in the rapid spread of the fire, the inadequacy of the means of emergency egress for the astronauts, and the need to recognize that all future such tests be classified as involving a higher level of hazard.

The following emerges from the preliminary views of the Board and the Board's preliminary recommendations:

(1) The risk of fire that could not be controlled or from which escape could not be made was considerably greater than was recognized when the procedures for the conduct of the test were established. Our experience with pure oxygen atmospheres included not only the successful Mercury and Gemini flights but a number of instances where a clearly positive source of ignition did not result in a fire. In one such instance an electric light bulb was shattered, exposing the incandescent element to the oxygen atmosphere without starting a fire.

(2) Our successful experience with pure oxygen atmospheres in Mercury and Gemini, our experience with the difficulty of storing and using hand-held equipment under zero-gravity conditions, and our experience with the difficulty of making sure before flight that no undiscovered items had been dropped or found their way into the complex maze of plumbing, wiring, and equipment in the capsule, led us to place in the Apollo 204 capsule such items as Velcro pads to which frequently used items could be easily attached and removed, protective covers on wire bundles, nylon netting to prevent articles dropped in ground testing from being lost under or behind equipment in the capsule, and a pad or cushion on which, in the planned escape exercise, the hatch could be placed without damage to the hatch itself or to the equipment in the spacecraft. While most of these were constructed of low-combustion-potential material, they were not so arranged as to provide barriers to the spread of a fire. Tests conducted in an Apollo-type chamber since the accident have shown that an oxygen fire in the capsule will spread along the surface of Velcro and along the edges of nylon netting much faster than through the material itself.

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(3) Soldered joints in piping carrying both oxygen and fluids were melted away, with resultant leakage contributing to the spread of the fire.

(4) The bursting of the capsule happened in such a way that the flames, as they rushed toward the rupture and exhausted through it, traveled over and around the astronauts' couches. Under these conditions, and with just a few seconds of time available, the astronauts could not reach the hatch and open it.

(5) This fire indicates that a number of items related to the design and performance of the environmental control unit will require the most careful examination and may require redesign.

Astronaut Borman, in commenting on his reactions to the conditions surrounding the Apollo 204 test and the subsequent knowledge he has gained as a result of serving on the Review Board, stated to Dr. Seamans, Dr. Thompson, and to me that he would not have been concerned to enter the capsule at the time Grissom, White and Chaffee did so for the test, and would not at that time have regarded the operation as involving substantial hazard. However, he stated that his work on the Board has convinced him that there were hazards present beyond the understanding of either NASA's engineers or astronauts. He believes the work of the Review Board will provide the knowledge and recommendations necessary to substantially minimize or eliminate them.

Dr. Thompson, Astronaut Borman, and Dr. Van Dolah have returned to Cape Kennedy and are proceeding with the work of the Board. This will require several weeks to complete.

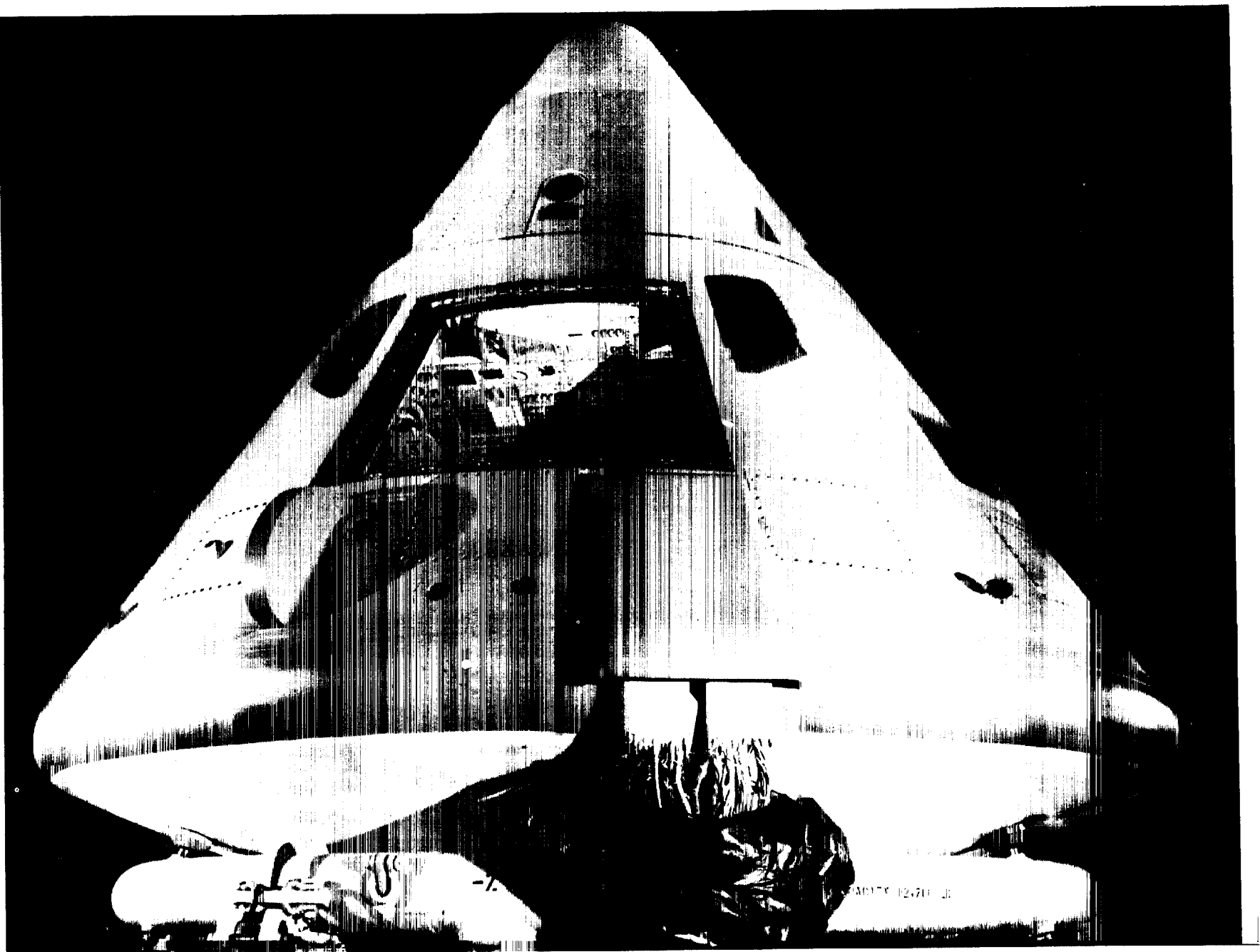
Chairman George Miller, of the House Committee on Science and Astronautics, has announced that as soon as the Board's work is complete, the Committee's Oversight Subcommittee, chaired by Congressman Olin Teague, will conduct a complete investigation of all factors related to the accident and NASA's actions to meet the conditions disclosed. Chairman Teague spent Friday and Saturday at Cape Kennedy with members of the Manned Space Flight Subcommittee, of which he is also Chairman, reviewing progress in the Apollo program. Dr. Seamans, Dr. George Mueller, and I will report further to him at 10 a.m., Monday, February 27.



**PART IV**

**HISTORY  
OF  
THE ACCIDENT**

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## PART IV - HISTORY OF SPACECRAFT 012 AND THE ACCIDENT

### 1. EVENTS FROM INITIATION OF FABRICATION UNTIL THE INITIATION OF THE "PLUGS OUT" TEST

Spacecraft 012, assigned to Mission AS-204, was built at North American Aviation, Inc., Space and Information Systems Division, Downey, California. Enclosure 1 shows sketches of the complete space vehicle, the spacecraft and the Command Module. Fabrication was begun in August 1964 and the basic structure was completed in September 1965. While the structure was being fabricated, each component of every subsystem was subjected to acceptance tests and subsystems were assembled. During this period a series of Preliminary Design Reviews were held between November 1964 and January 1965. Installation and final assembly of subsystems into the Command Module took place between September 1965 and March 1966. Critical Design Reviews were held during February and March 1966. Check-out of all subsystems was then initiated followed by integrated testing of all spacecraft subsystems. A series of reviews of the spacecraft and checkout was held during the checkout and integrated testing process. A two-phase Customer Acceptance Readiness Review was conducted by NASA at Downey in conjunction with NAA in July and August 1966. After the August review NASA issued a Certificate of Flight Worthiness and authorized the spacecraft to be shipped to the John F. Kennedy Space Center (KSC), Florida. The Certificate included a listing of open items and work to be completed at KSC.

The Command Module was received at KSC on August 26, 1966. It was mated with the Service Module in the altitude chamber at KSC early in September 1966 and alignment, subsystems and system verification tests and functional checks were performed. Many open design change orders were completed and various malfunctions were noted and corrected. The first combined systems tests were begun on September 14 and completed on October 1, 1966. Several malfunctions were noted and correction of some of these was deferred to a later date.

A design Certification Review was held at NASA Headquarters during September and October 1966. This detailed review was conducted by a Board chaired by the Associate Administrator for Manned Space Flight. Board Members were Office of Manned Space Flight Center Directors. This Board issued a Design Certification Document on October 7, 1966 which certified the design as flightworthy, pending satisfactory resolution of listed open items.

After the combined systems tests were completed at KSC in the altitude chamber, the first manned test in this facility was performed. This test was conducted in air at sea level pressure and was made to verify total spacecraft system operation. The test was initiated on October 10 and discontinued on October 11 to replace bent umbilical pins. The test was begun again on October 12 and completed on October 13. On October 14 and 15, an unmanned test was performed at altitude pressures using oxygen to verify spacecraft system operation under these conditions before a manned altitude test was run. The manned test (with the flight crew) was initiated on October 18 but was discontinued after reaching a simulated altitude of 13,000 feet because of the failure of a transistor in one of the inverters in the spacecraft. The inverter was replaced and the test was completed on October 19. A second manned altitude test (with the backup crew) was initiated on October 21 but it was discontinued when a failure occurred in an oxygen system regulator in the spacecraft Environmental Control System. This regulator was removed and found to have a design deficiency. While redesign was being accomplished various spacecraft work items were completed..

On October 27 the Environmental Control Unit was removed and returned to the factory for a design change to the water/glycol evaporator.

During this period a propellant tank had ruptured in the Service Module of Spacecraft 017 at Downey. Therefore, it was decided that the tanks on the Spacecraft 012 Service Module should be checked by special testing at KSC. In order to conduct this testing in parallel with further checking of the Spacecraft 012 Command Module, the Command Module was removed from the altitude chamber. The Service Module was later removed for tests related to the propellant tanks. The Service

Module and Command Module were reinstalled in the altitude chamber and the ECU was installed. A water/glycol leak developed in the ECU, and it was again returned to the factory for further examination of the leak problem. It was returned on December 14, 1966.

Also, during this period on December 21, 1966 the Apollo Program Director conducted a Recertification Review which closed out the majority of the open items remaining from previous reviews.

After The Command and Service Modules were reinstalled in the altitude chamber and testing in the chamber was resumed. The sea level and unmanned altitude tests were conducted on December 27 and 28 and the manned altitude test with the backup flight crew was conducted on December 29 and 30.

It should be noted that this final manned test in the altitude chamber was very successful with all spacecraft systems functioning normally. At the post-test debriefing the backup flight crew expressed their satisfaction with the condition and performance of the spacecraft.

It should also be noted that in the altitude chamber tests the Command Module was pressurized with pure oxygen four times at pressures greater than 14.7 psia for a total time of 6 hours and 15 minutes. The total time was about 2½ times longer than the time the Command Module was pressurized with oxygen during the test which was in progress when the accident occurred.

The Command Module was removed from the altitude chamber on January 3, 1967 and the spacecraft was mated to the launch vehicle on January 6 at Launch Complex 34. Various tests and equipment installations and replacements were then performed.

The system was determined to be ready for the initiation of the Plugs-Out Test on January 27, 1967.

Of the many events which took place at KSC subsequent to the arrival of the spacecraft a few stand out as possible indications of deficiencies in the program and some appear to have possible relation to the fire.

The events that possibly may be related to the fire are those concerned with the occasions when water/glycol spillage or leakage from the Environmental Control System was noted. This may be of significance in that water/glycol coming into contact with electrical connectors can cause corrosion of these connectors. Dried water/glycol on wiring insulation leaves a residue which is electrically conductive and combustible. Of the six recorded instances where water/glycol spillage or leakage occurred (a total of 90 ounces leaked or spilled is noted in the records) the records indicate that this resulted in wetting of conductors and wiring on only one occasion. Action was taken to clean the water/glycol from the connectors and wiring on this one occasion. There is no evidence which indicates that damage resulted to the conductors or that faults were produced on connectors due to water/glycol which contributed to the fire. If the cleaning were inadequate, residue would have remained on the wires. Also, undetected wetting could have occurred which would leave a residue. Small quantities of water/glycol were found in the Command Module after the fire. This, however, could have been due to water/glycol line breakage which is known to have occurred during the fire. And while water/glycol and its residue may have contributed to the spread of the fire there is no positive evidence that residue was related to the ignition of the fire.

The number of open items at the time of shipment of Command Module 012 was not known. There were 113 significant Engineering Orders not accomplished at the time Command Module 012 was delivered to NASA; 623 Engineering Orders were released subsequent to delivery. Of these, 22 were recent releases which were not recorded in configuration records at the time of the accident.

The effort and rework required on Spacecraft 012 at KSC was greater than that experienced on the first manned Gemini spacecraft. However since the Apollo Spacecraft are considerably more com-

plex than Gemini Spacecraft this does not necessarily indicate that the quantity of problems encountered was excessive. There is, however, an inference that the design, qualification and fabrication process may not have been completed adequately prior to shipment to KSC.

Another item should be noted when considering the problems that were found at KSC including some of the problems encountered in the Plugs-Out Test prior to the fire. The prime purpose of all tests conducted prior to launch is to verify and demonstrate that the space vehicle ground support equipment, procedures and personnel are all ready for flight operations. Many of the tests involve a "first-time" operation particularly in an overall sense. Therefore, inherent in the verification process is the likelihood that faults will be found in procedures and in equipment. This Plugs-Out Test had not been classified as hazardous because only those tests involving fueled vehicles, hypergolic propellants, cryogenic systems, high pressure tanks, live pyrotechnics or altitude chamber tests were routinely classified as hazardous.

## 2. EVENTS FROM INITIATION OF THE PLUGS-OUT TEST UNTIL THE T-10 MINUTE HOLD

The purpose of the Space Vehicle Plugs-Out Integrated Test, Operational Checkout Procedures (OCP) FO-K-0021-1, Spacecraft 012 is to demonstrate all space vehicle systems and operational procedures in as near a flight configuration as is practical and to verify their capability in a simulated launch. System verification is performed, an abbreviated final countdown conducted and a flight simulation made. All communication and instrumentation systems are activated and proper measurements are monitored at appropriate ground stations. At the start of the simulated flight, umbilicals are disconnected and the spacecraft is on simulated fuel-cell power.

Specific objectives of this test for Spacecraft 012 as stated in the Final Procedure Document were:

- a. To verify overall spacecraft/launch vehicle compatibility and demonstrate proper function of spacecraft systems with all umbilicals and Ground Support Equipment disconnected.
- b. To verify no electrical interference at the time of umbilical disconnect.
- c. To verify astronaut emergency egress procedures (unaided egress) at the conclusion of the test.

The preliminary outline for this test procedure was written by North American Aviation, Inc. (NAA) in July 1966. The test procedure was reviewed and revised periodically over the next few months. In September the flight crew requested that emergency egress practice which was not in the original test outline be added. This addition was requested because a subsequent test, Countdown Demonstration, would involve a fully fueled Launch Vehicle and this latter test was identified as hazardous. This egress test was then added to the Space Vehicle Plugs Out Integrated Test.

The first draft of the Procedure was issued on September 26, 1966. After informal review and revision a second draft was issued on October 19, 1966. After formal review by both NASA and NAA, and further revision the formally approved procedure was issued on December 13, 1966. This procedure was reviewed at KSC and operational and minor technical changes made. A major revision was issued at 5:30 p.m. EST on January 26, 1967 and 4 additional pages were issued at 10:00 a.m. EST on January 27, 1967.

The Plugs-Out Test was initiated on January 27, 1967 at 12:55 GMT (7:55 a.m. EST) when power was applied to the spacecraft for this test. After completion of initial verification tests of system operation the flight crew entered the Command Module. The Command Pilot entered at 18:00 GMT (1:00 p.m. EST) followed by the Pilot and Senior Pilot. The Command Pilot noted an odor in the Spacecraft Environmental Control System suit oxygen loop and the count was held at 18:20 GMT while a sample of the oxygen in this system was taken. This odor has been determined from subsequent analysis not to be related to the fire. The count was resumed at 19:42 GMT with hatch installation and subsequent cabin purge with oxygen beginning at 19:45 GMT. Communication difficulties were encountered and the count was held at approximately 22:40 GMT to troubleshoot the problem. Various final countdown functions were still performed during the hold as communications permitted. From 22:45 GMT until about 22:53 GMT the flight crew interchanged equipment related to the communications systems in an effort to isolate the communications system problem. This problem consisted of

a continuously live microphone that could not be turned off by the crew. The live microphone condition was first noted by the test crew about 22:25 GMT and records indicate that the condition first occurred between about 20:57 GMT and 22:18 GMT. During the troubleshooting period problems developed in the ability of various ground stations to communicate with one another and with the crew. None of the communications problems appear to have had a direct bearing on the fire.

By 22:20 GMT (6:20 p.m. EST) all final countdown functions up to the transfer to simulated fuel cell power were completed and the count was held at T-10 minutes pending resolution of the communications problems.

### 3. EVENTS FROM THE INITIATION OF THE T-10 MINUTE HOLD AT 23:20 GMT UNTIL THE REPORT OF FIRE

From the start of the T-10 minute hold at 23:20 GMT until about 23:30 GMT there are no events that appear to be related to the fire. The major activity during this period was routine troubleshooting of the communications problem. The records show that except for the communications problem all systems were operating normally during this period. There were no voice transmissions from the spacecraft from 23:30:14 GMT until the transmission reporting the fire which began at 23:31:04.7 GMT (6:31:04.7 p.m. EST).

During the period beginning about 30 seconds before the report there are indications of crew movement. These indications are provided by the data from the Biomedical Sensors, the Command Pilot's live mike, the Guidance and Navigation System and the Environmental Control System.

There is, however, no evidence as to what this crew movement was or that it was related to the fire.

The biomedical data indicate that just prior to the fire report the Senior Pilot was performing essentially no activity (or was in the baseline "rest" condition) until about 23:30:21 GMT when a slight increase in pulse and respiratory rate was noted. At 23:30:30 GMT the electrocardiogram indicates some muscular activity for several seconds. Similar indications are noted at 23:30:39 GMT. The data show increased activity but are not indicative of an alarm type of response. By 23:30:45 GMT, all of the biomedical parameters had reverted to the baseline "rest" level.

Beginning at about 23:30 GMT, the Command Pilot live microphone transmitted brushing and tapping noises which are indicative of movement. The noises were similar to those transmitted earlier in the test by the live mike when the Command Pilot is known to have been moving. These sounds end at 23:30:58.6 GMT.

Any significant crew movement results in minor motion of the Command Module. This motion is detected by the Guidance and Navigation System and is indicative of crew movement; however, the type of movement cannot be determined. Data from this system indicate a slight movement at 23:30:24 GMT with more intense activity beginning at 23:30:39 GMT and ending at 23:30:44 GMT. More movement begins at 23:31:00 GMT and continues until loss of data transmission during the fire.

Increases of oxygen flow rate to the crew suits also indicate movement. All suits have some small leakage. This leakage rate varies with crew positions. Earlier in the Plugs-Out Test, the crew reported that a particular movement, the nature of which was unspecified, provided increased flow rate. This is also confirmed from the flow rate data records. The flow rate shows a gradual rise at 23:30:24 GMT which reaches the limit of the sensor at 23:30:59 GMT.

There is a variation at 23:30:50 GMT in the signal output from the gas chromatograph cable (the gas chromatograph was not installed in the Command Module). When the gas chromatograph is not connected, the cable acts as an antenna. Thus, changes in the electromagnetic field within the spacecraft are sensed when the cable is approached closely, touched or moved or voltage fluctuations occur

in other equipment. Variations found in the signal level from the gas chromatograph cable at earlier times in the test have been correlated with either crew movement or voltage transients when equipment was turned off or on at these earlier times. The variation at 23:30:50 GMT, may have resulted because it was touched or approached by the crew since there does not appear to be any voltage transient condition at this time which could have given the observed signal.

A significant voltage transient was recorded at 23:30:54.8 GMT. The records show a surge in the AC Bus 2 voltage.

Several other parameters being measured also showed anomalous behaviour at this time. There was a 1.7 second dropout in signal from the C-Band decoder and transmitter outputs, a brief dropout of the VHF-FM carrier, a fluctuation in the rotation controller null outputs and a fluctuation in the gas chromatograph signal.

#### 4. EVENTS FROM THE REPORT OF FIRE UNTIL CREW REMOVAL

The events that occurred during this period can be comprehended most readily by examination of Enclosures 2 through 6. These enclosures show a sketch of Launch Complex 34, the Space Vehicle in the service tower and the interior of a mock-up of a Command Module showing detailed reconstruction of Spacecraft 012.

Beginning at 23:31:04.7 GMT (6:31:04.7 P.M. EST), the crew gave the first verbal indication of an emergency - a fire in the Command Module was reported.

Emergency procedures called for the Senior Pilot, occupying the center couch, to unlatch and remove the hatch while retaining his harness buckled. A number of witnesses who observed the television picture of the Command Module hatch window during this stage of the fire discerned motion that suggests that the Senior Pilot was reaching for the inner hatch handle. The Senior Pilot's harness buckle was found unopened after the fire, indicating that he initiated the standard hatch-opening procedure. Data from the Guidance and Navigation System indicate considerable activity within the Command Module after the fire was discovered. This activity is consistent with movement of the crew prompted by proximity of the fire or with the undertaking of standard emergency egress procedures.

Personnel located on adjustable level 8 (A-8) adjacent to the Command Module responded to the report of the fire. The Pad Leader ordered crew egress procedures to be started and technicians started toward the White Room which surrounds the hatch and into which the crew would step upon egress. Then the Command Module ruptured.

All transmission of voice and data from the spacecraft terminated by 23:31:22.4 GMT, three seconds after rupture. Witnesses monitoring television showing the hatch window report that flame spread from the left to the right side of the Command Module and shortly thereafter covered the entire visible area.

Flames and gases flowed rapidly out of the ruptured area, spreading flames into the toroidal space between the Command Module pressure vessel and heat shield, through access hatches and into levels A-8 and A-7 of the service structure. These flames ignited combustibles, endangered pad personnel, and impeded rescue efforts. The burst of fire, together with the sounds of rupture, caused several pad personnel to believe that the Command Module had exploded or was about to explode. Pad personnel fled from the immediate area.

The immediate reaction of all personnel on level A-8 was to evacuate the level. This reaction was promptly followed by a return to effect rescue. Upon running out on the swing arm from the umbilical tower, several personnel obtained a fire extinguisher and returned along the swing arm to the White Room to begin rescue efforts. Others obtained fire extinguishers from various areas of the service structure and rendered assistance in fighting the fires.



The time interval between exit to the swing arm and return to the White Room is estimated variously by the participants. Persons viewing television monitors could not see movement early in the White Room because of heavy smoke. Approximately one minute and thirty seconds after the first crew report of the fire the Pad Leader reported over his headset that attempts had been started to remove the hatches. This report was made after the Pad Leader had gone out on the swing arm, returned and entered the White Room one or two times and left to reach breathable air and his headset. It is therefore estimated that attempts to remove the hatches began one minute after the fire was first reported.

Three hatches were installed on the Command Module. The outermost hatch, called the boost protective cover (BPC) hatch, is part of the cover which shields the Command Module during launch and is jettisoned prior to orbital operation. The middle hatch is termed the ablative hatch and becomes the outer hatch when the BPC is jettisoned after launch. The inner hatch closes the pressure vessel wall of the Command Module and is the first hatch to be opened by the crew in an unaided crew egress.

The outer or BPC hatch was in place but not fully latched because of distortion in the BPC caused by wire bundles temporarily installed for the test. The middle hatch and inner hatch were in place and latched after crew ingress.

Although the BPC hatch was not fully latched it was necessary to insert a specially-designed tool into the hatch in order to provide a hand-hold for lifting the hatch from the Command Module. At this time the White Room was filling with dense, dark smoke from the Command Module interior and from secondary fires throughout level A-8. While some personnel were able to locate and don operable gas masks others were not. Some proceeded without masks while others attempted without success to render masks operable. Even operable masks were unable to cope with the dense smoke present because they were designed for use in toxic rather than dense smoke atmospheres.

Visibility in the White Room was virtually zero. It was necessary to work essentially by touch since visual observation was limited to a few inches at best. A hatch removal tool was in the White Room. Once the small fire near the BPC hatch had been extinguished and the tool located the Pad Leader and an assistant removed the BPC hatch. Although the hatch was not latched removal was difficult.

The personnel who removed the BPC hatch could not remain in the White Room because of the smoke. They left the White Room and passed the tool which was necessary to open each hatch to other individuals. A total of five individuals took part in opening the three hatches and each made several trips into the White Room and out for breathable air.

The middle hatch was removed with less effort than was required for the outer or BPC hatch.

The inner hatch was unlatched and an attempt was made to raise it from its support and to lower it to the Command Module floor. The hatch could not be lowered the full distance to the floor and was instead pushed to one side. When the inner hatch was opened intense heat and a considerable amount of smoke issued from the interior of the Command Module.

When the Pad Leader ascertained that all hatches were open, he left the White Room, proceeded a few feet along the swing arm, donned his headset and reported this fact. From a voice tape it has been determined that this report came approximately five minutes, twenty-seven seconds after the first report of the fire. The Pad Leader estimates that his report was made no more than thirty seconds after the inner hatch was opened. Therefore, it is concluded that all hatches were opened and the two outer hatches removed approximately five minutes after the report of fire or at about 23:36 GMT. A log maintained by a person monitoring voice transmissions from level A-8 sets the time of the Pad Leader's report at 23:36 GMT. All records in this log are noted in minutes with no indication of seconds. Medical opinion, based on autopsy reports, has concluded that chances of resuscitation decreased rapidly once consciousness was lost and that resuscitation was impossible by 23:36 GMT.

Visibility within the Command Module was extremely poor. Although the lights remained on, they could be perceived only dimly. No fire was observed. Initially, the crew was not seen. The personnel who had been involved in removing the hatches attempted to locate the crew without success.

Throughout this period, other pad personnel were fighting secondary fires on level A-8. There was considerable fear that the launch escape tower, mounted above the Command Module, would be ignited by the fires below and destroy much of the launch complex.

Shortly after the report of the fire, a call was made to the fire department. From log records, it appears that the fire apparatus and personnel were dispatched at about 23:32 GMT. After hearing the report of the fire, the doctor monitoring the test from the blockhouse near the pad proceeded to the base of the umbilical tower.

The exact time at which firemen reached Level A-8 is not known. Personnel who opened the hatches unanimously state that all hatches were open before any firemen were seen on the level or in the White Room. The first firemen who reached Level A-8 state that all hatches were open, but that the inner hatch was inside the Command Module, when they arrived. This places arrival of the firemen after 23:36 GMT. It is estimated, on the basis of tests, that seven to eight minutes were required to travel from the fire station to the launch complex and to ride the elevator from the ground to Level A-8. Thus, the estimated time of firemen arrival at level A-8 is shortly before 23:40 GMT.

When the firemen arrived, the positions of the crew couches and crew could be perceived through the smoke but only with great difficulty. An unsuccessful attempt was made to remove the Senior Pilot from the Command Module.

Initial observations and subsequent inspection reveal the following facts. The Command Pilot's couch (the left hand couch) was in the "170 degree position", in which it is essentially horizontal throughout its length. The foot restraints and harness were released and the inlet and outlet oxygen hoses were connected to the suit. The electrical adapter cable was disconnected from the communications cable. The Command Pilot was lying supine on the aft bulkhead or floor of the Command Module, with his helmet visor closed and locked and with his head beneath the Pilot's head rest and his feet on his own couch. A fragment of his suit material was found outside the Command Module pressure vessel five feet from the point of rupture. This indicates that his suit had failed prior to the time of rupture (23:31:19.4 GMT) allowing convection currents to carry the suit fragment through the rupture.

The Senior Pilot's couch (the center couch) was in the "96 degree" position in which the back portion is horizontal and lower portion in the raised position. The buckle releasing the shoulder straps and lap belts was not opened. The straps and belts were burned through. The suit oxygen outlet hose was connected but the inlet hose was disconnected. The helmet visor was closed and locked and all electrical connections were intact. The Senior Pilot was lying transversely across the Command Module just below the level of the hatchway.

The Pilot's couch (the right hand couch) was in the "264 degree" position in which the back portion is horizontal and the lower portion dropped toward the floor. All restraints were disconnected, all hoses and electrical connections were intact and the helmet visor was closed and locked. The Pilot was supine on his couch.

From the foregoing it has been determined that in all probability the Command Pilot left his couch to avoid the initial fire, the Senior Pilot remained in his couch as planned for emergency egress, attempting to open the hatch until his restraints burned through and the Pilot remained in his couch to maintain communications until the hatch could be opened by the Senior Pilot as planned. With a slightly higher pressure inside the Command Module than outside, opening the inner hatch is impossible because of the resulting force on the hatch. Thus the inability of the pressure relief system to cope with pressure increase due to the fire made opening of the inner hatch impossible until after cabin rupture,

and after rupture the intense and widespread fire together with rapidly increasing carbon monoxide concentrations further prevented egress.

Whether the inner hatch handle was moved by the crew cannot be determined because the opening of the inner hatch from the White Room also moves the handle within the Command Module to the unlatched position.

Immediately after the firemen arrived, the Pad Leader on duty was relieved to allow treatment for smoke inhalation. He had first reported over the headset that he could not describe the situation in the Command Module. In this manner he attempted to convey the fact that the crew was dead to the Test Conductor without informing the many people monitoring the communication channels. Upon reaching the ground the Pad Leader told the doctors that the crew was dead. The three doctors proceeded to the White Room and arrived there shortly after the arrival of the firemen. The doctors estimate their arrival to have been at 23:45 GMT. The second Pad Leader reported that medical support was available at approximately 23:43 GMT. The three doctors entered the White Room and determined that the crew had not survived the heat, smoke, and thermal burns. The doctors were not equipped with breathing apparatus, and the Command Module still contained fumes and smoke. It was determined that nothing could be gained by immediate removal of the crew. The firemen were directed to stop removal efforts

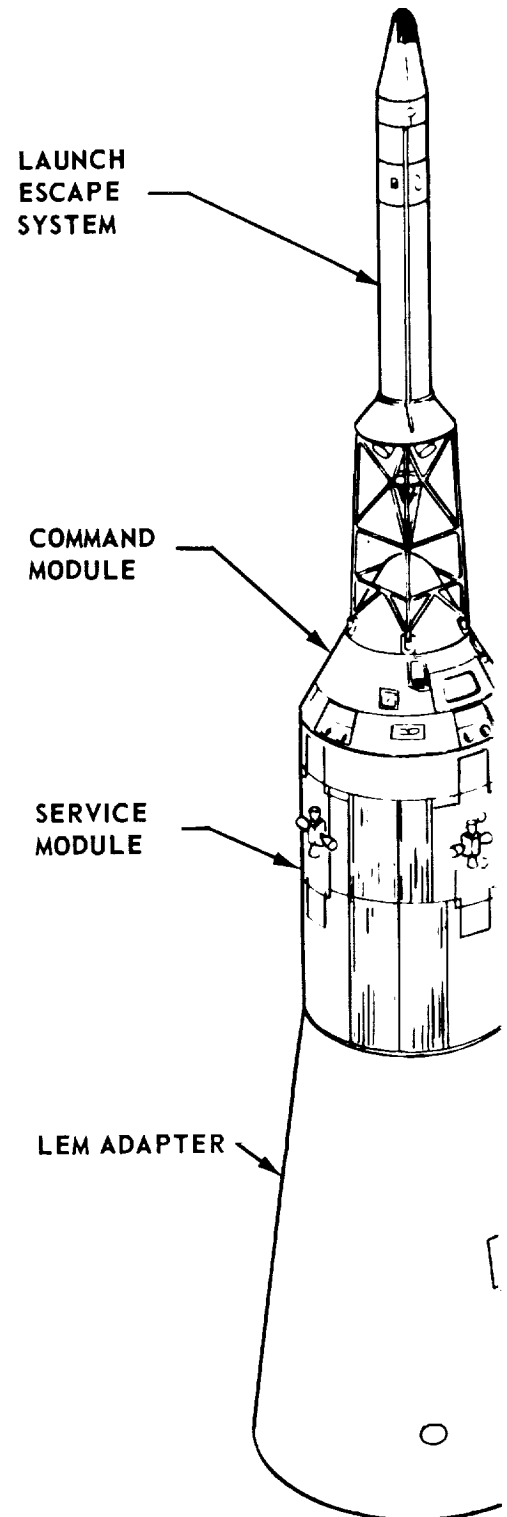
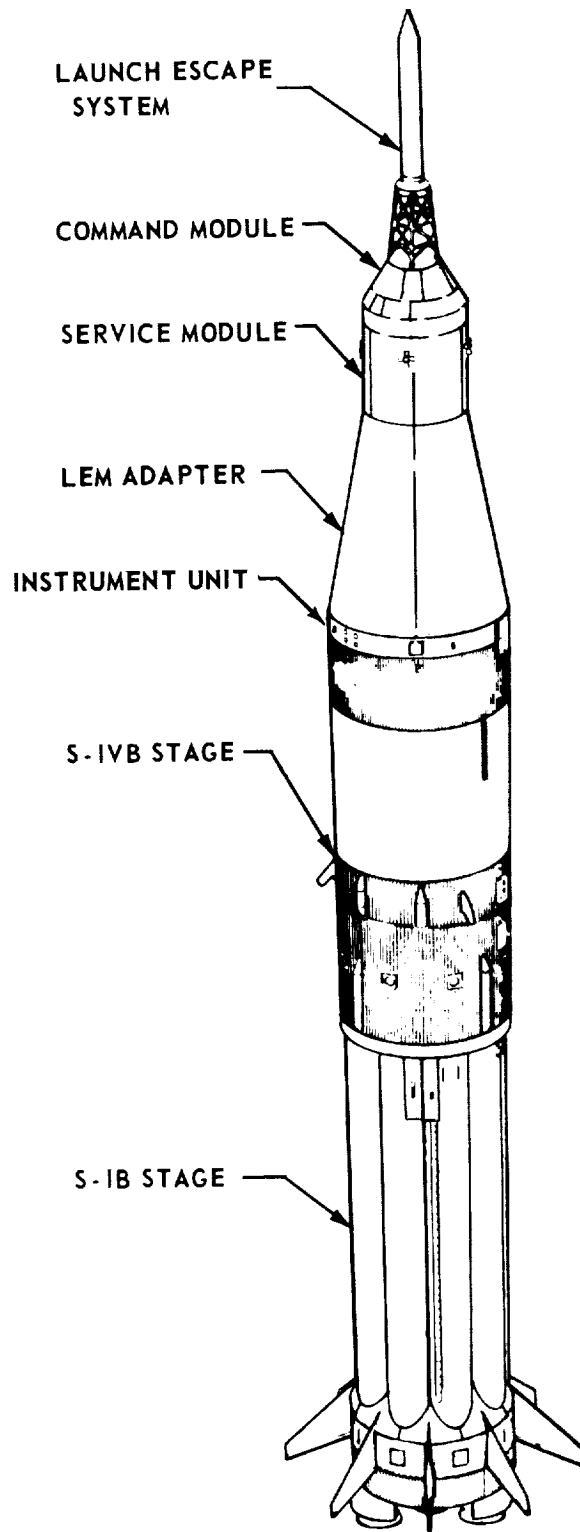
When the Command Module had been adequately ventilated, the doctors returned to the White Room with equipment for crew removal. It became apparent that extensive fusion of suit material to melted nylon from the spacecraft would make removal very difficult. For this reason it was decided to discontinue efforts at removal in the interest of accident investigation and to photograph the Command Module with the crew in place before evidence was disarranged.

Photographs were taken, and the removal efforts resumed at approximately 5:30 GMT (12:30 a.m. EST) on January 28. Removal of the crew took approximately 90 minutes and was completed about seven and one-half hours after the accident.

#### **LIST OF ENCLOSURES**

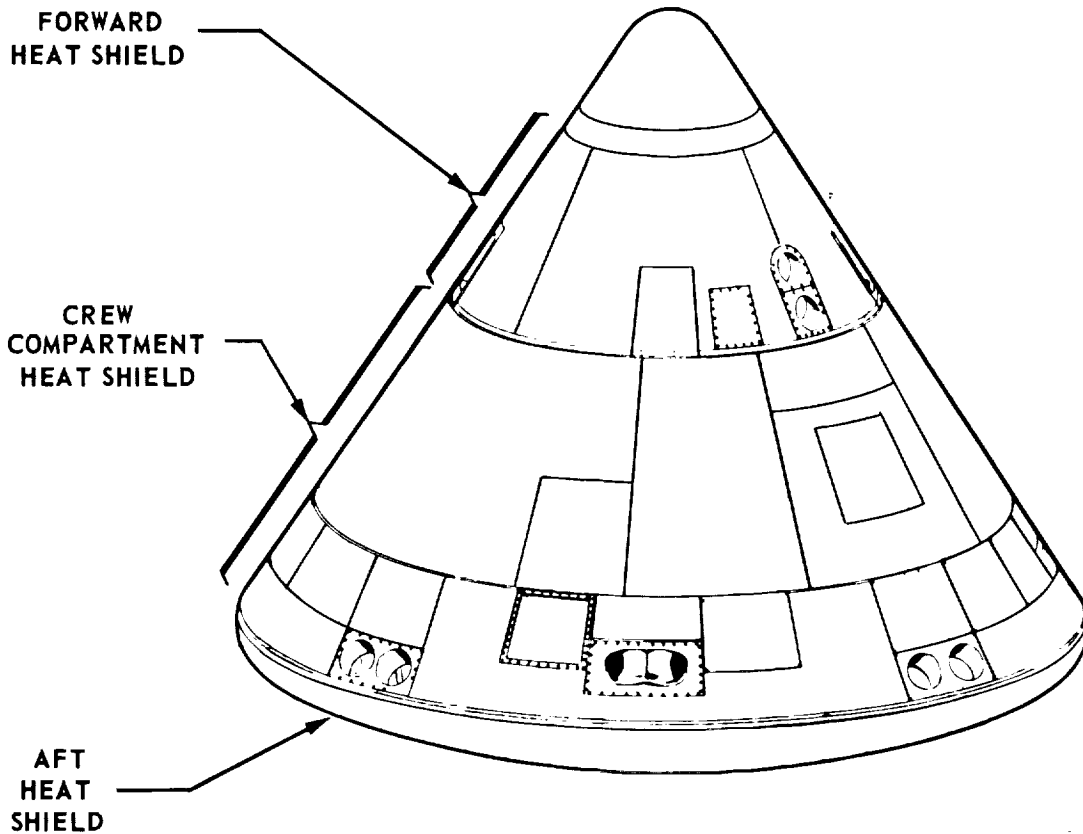
##### **Enclosure**

- IV-1 Schematic of the Complete Space Vehicle, the Spacecraft and the Command Module.
- IV-2 Aerial view of Complex 34 with Supporting Facilities.
- IV-3 Schematic of Spacecraft Launch Vehicle in Service Structure with Access Arms Extended.
- IV-4 Drawing of Umbilical Tower, Access Arm and White Room Positioned at the Command Module.
- IV-5 Photograph - Interior of a Mock-up Command Module, Without Couches, Configured Similar to Command Module 012 at the Time of the Accident.
- IV-6 Photograph - Interior of a Mock-up Command Module, With Couches, Configured Similar to Command Module 012.



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APOLLO COMMAND MODULE

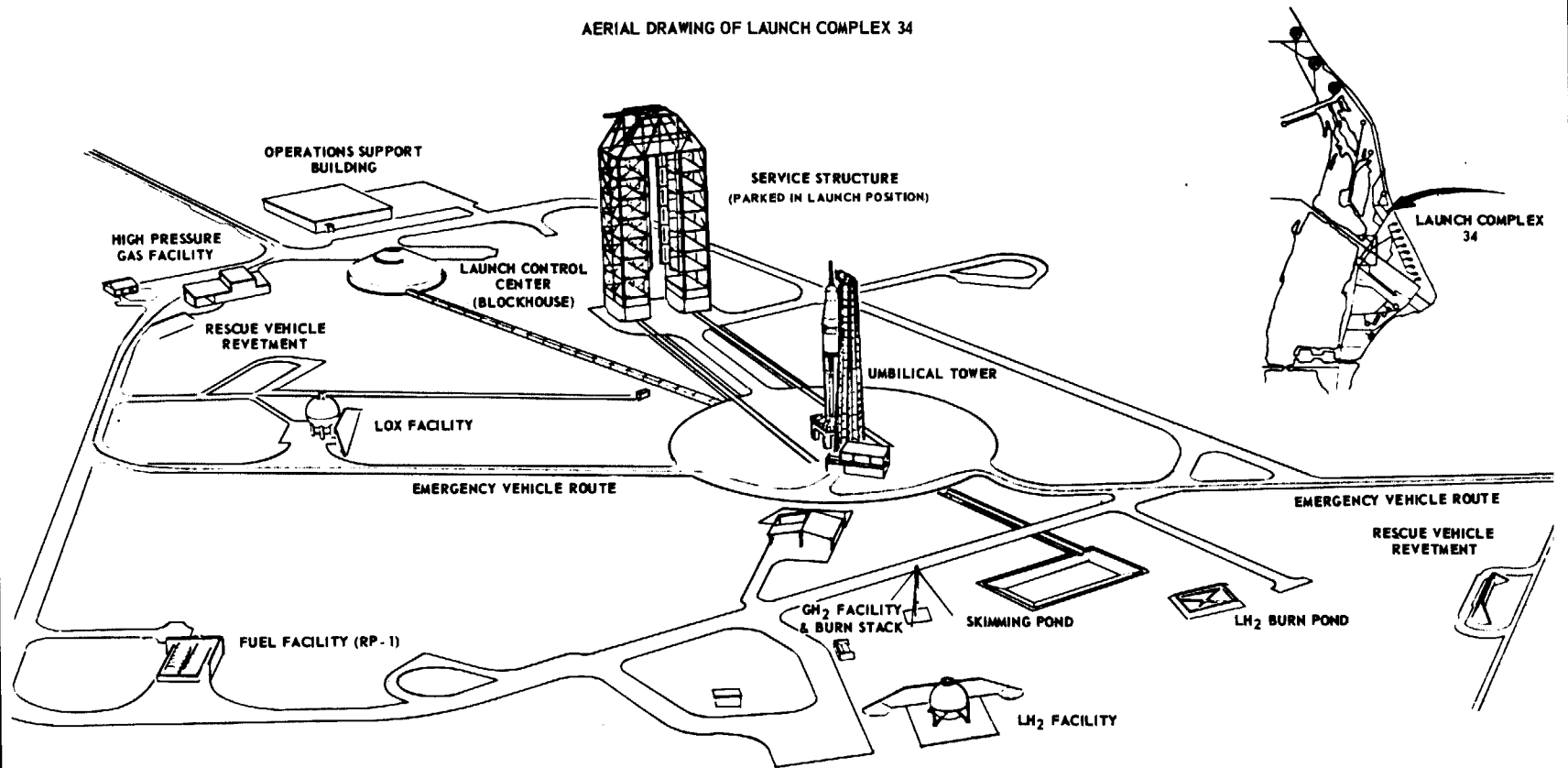
ENCLOSURE IV - 1

4-9 / 4-10

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2.

AERIAL DRAWING OF LAUNCH COMPLEX 34

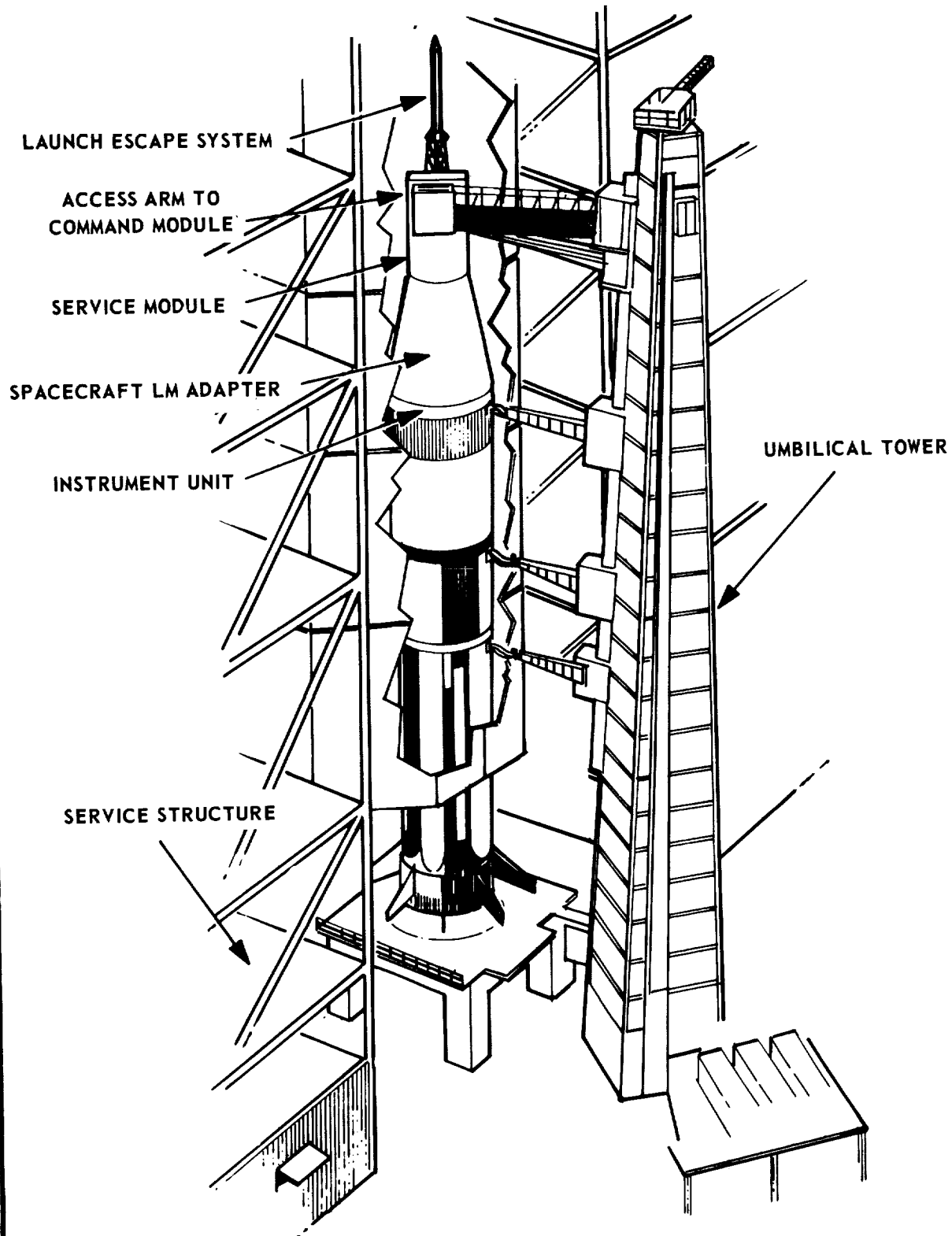


ENCLOSURE IV-2

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VIEW OF SPACECRAFT LAUNCH VEHICLE IN SERVICE STRUCTURE  
WITH ACCESS ARMS EXTENDED



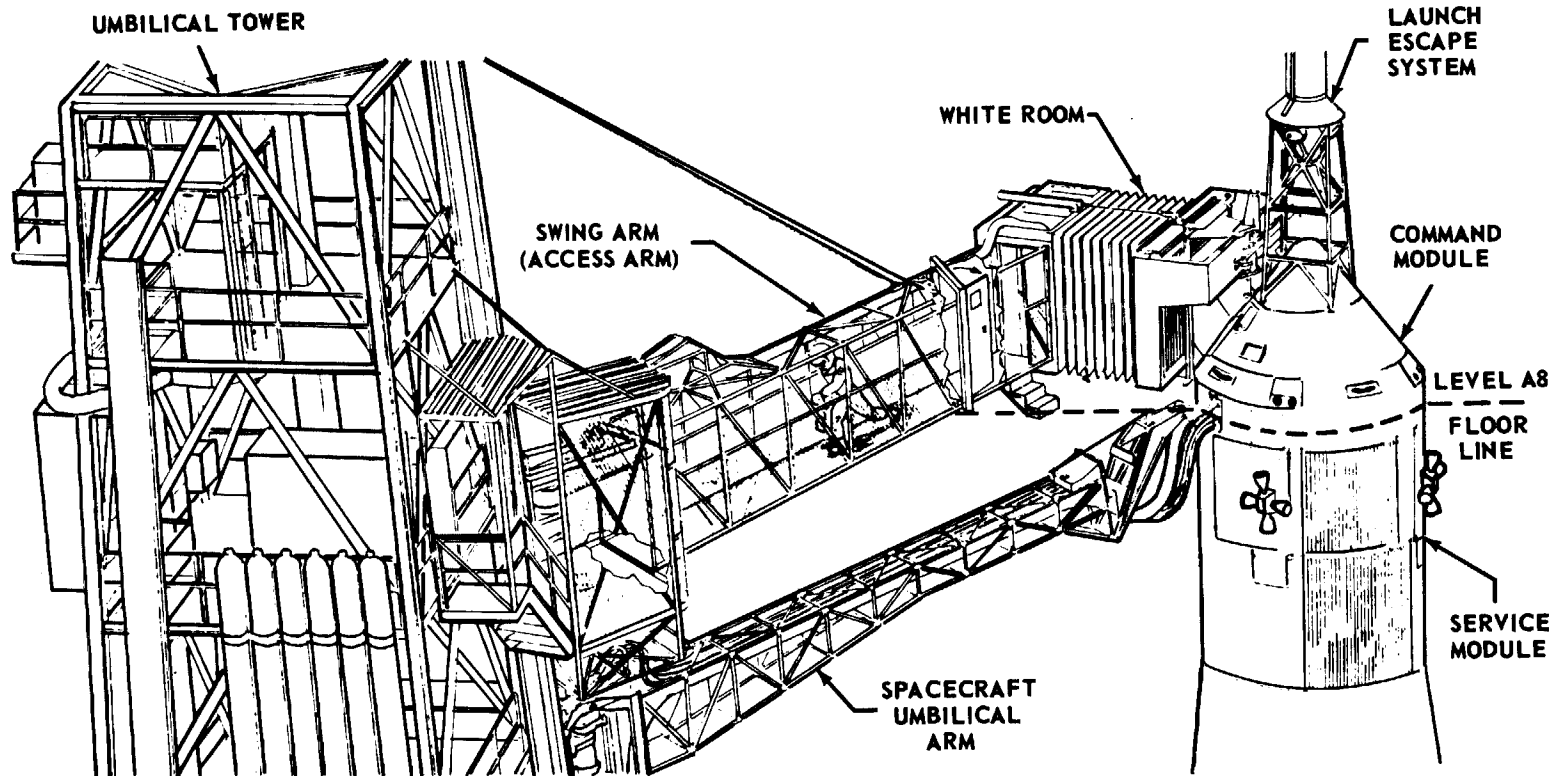
ENCLOSURE IV-3

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# LC-34 EGRESS ROUTE FOR ASTRONAUTS



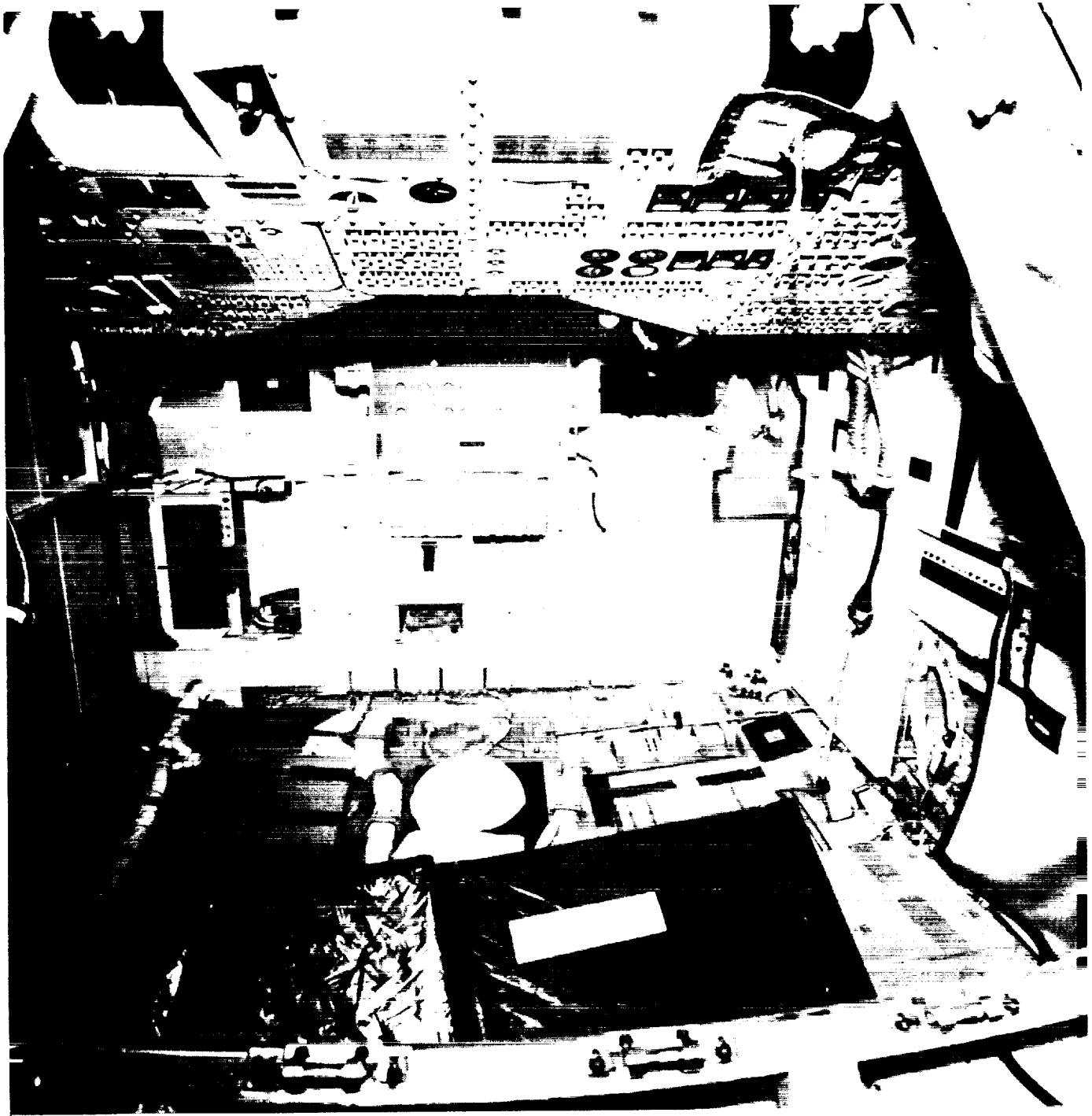
ENCLOSURE IV-4

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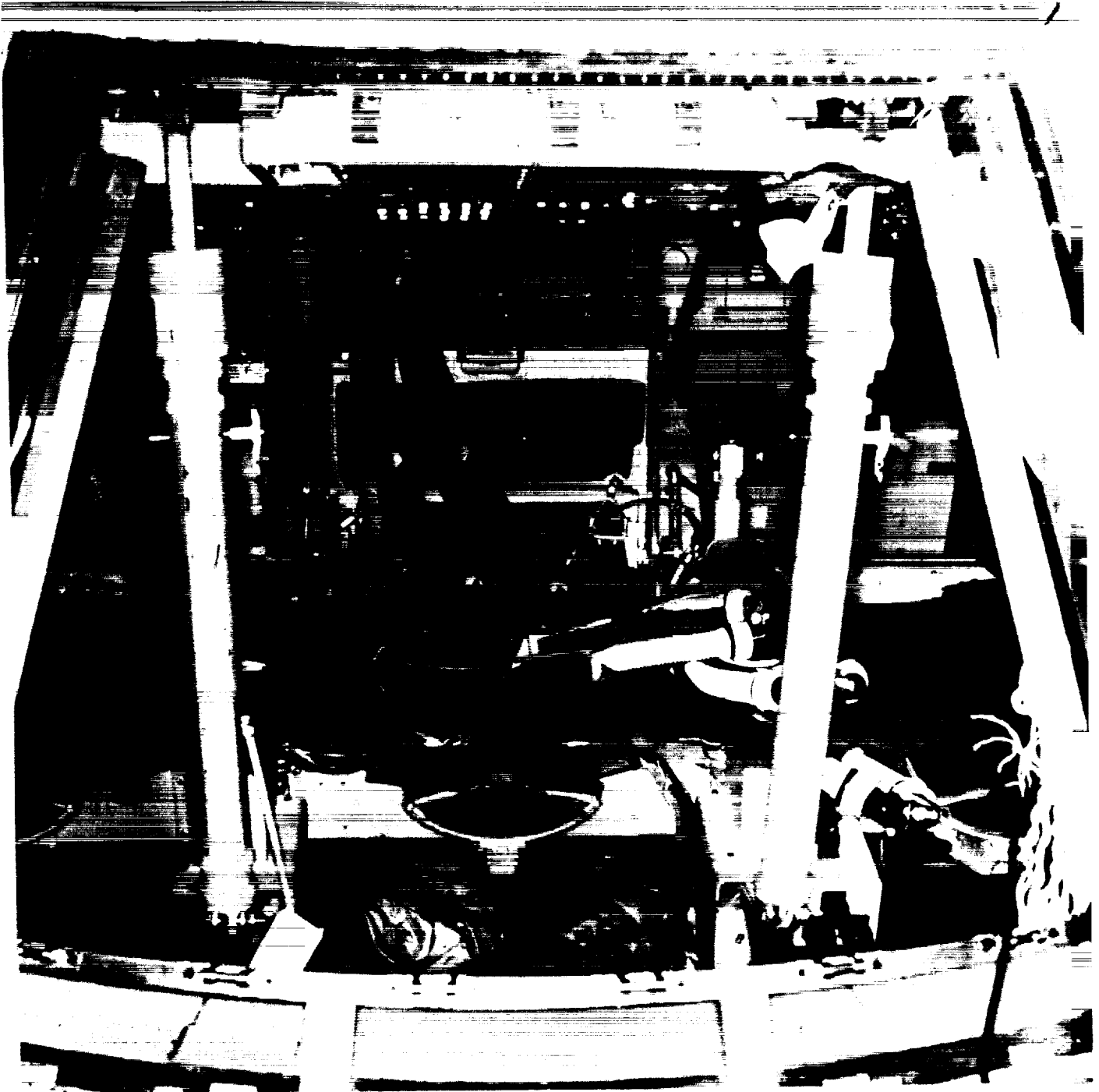


VIEW OF COMMAND MODULE MOCKUP INTERIOR LESS COUCHES

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ENCLOSURE IV-5

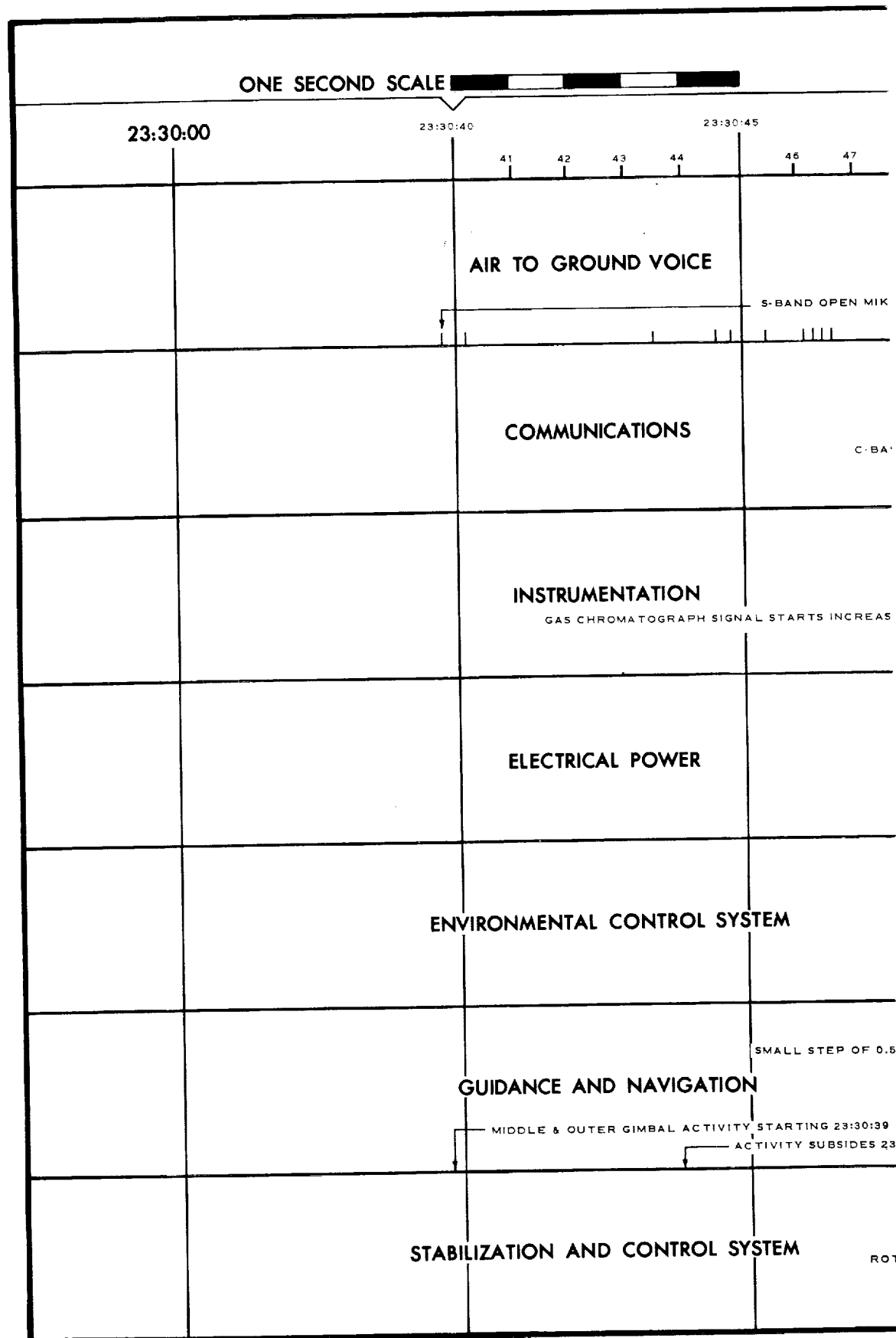
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VIEW OF COMMAND MODULE MOCKUP INTERIOR, COUCHES INSTALLED

ENCLOSURE IV-6

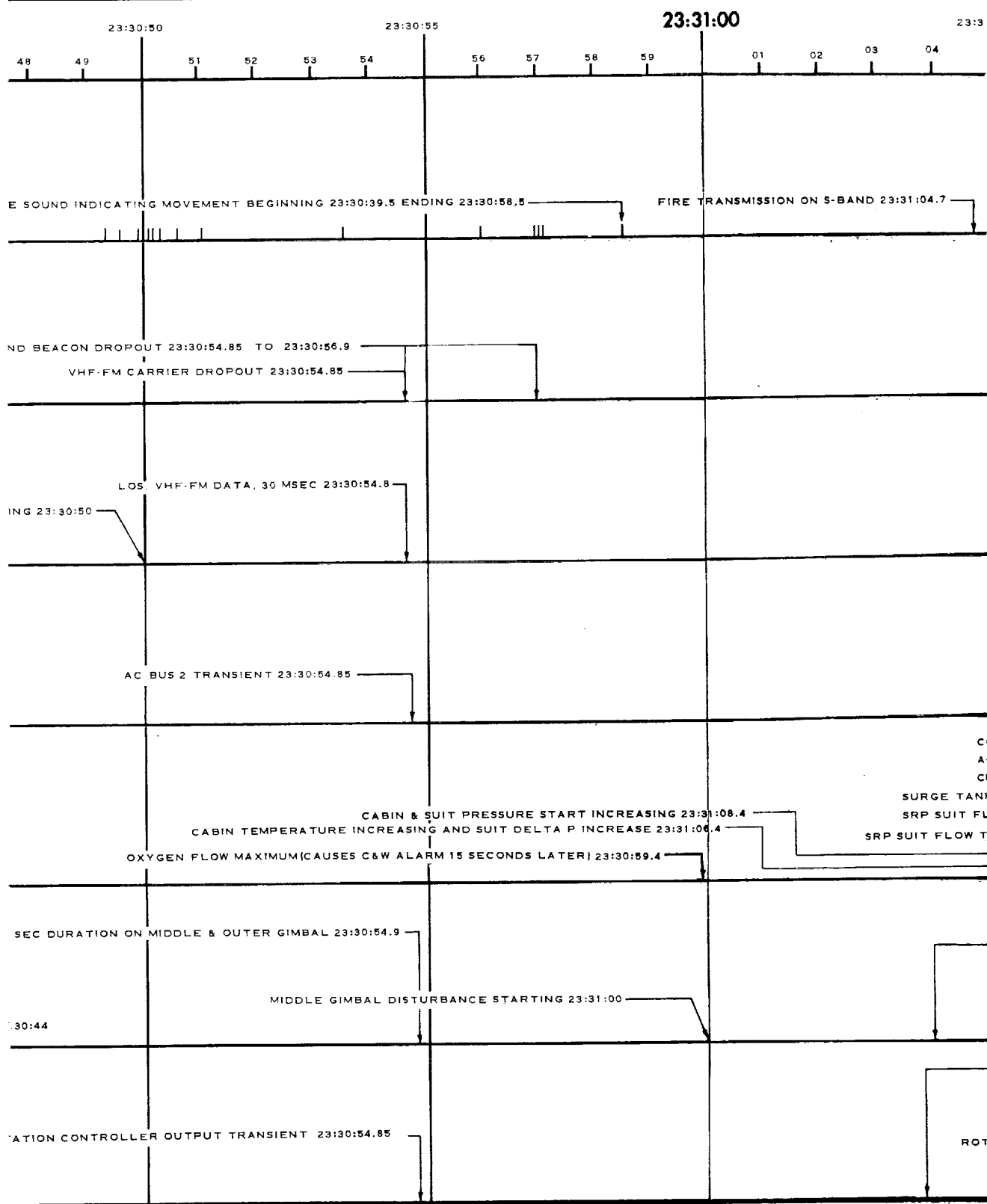
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# SEQUENCE OF EVENTS

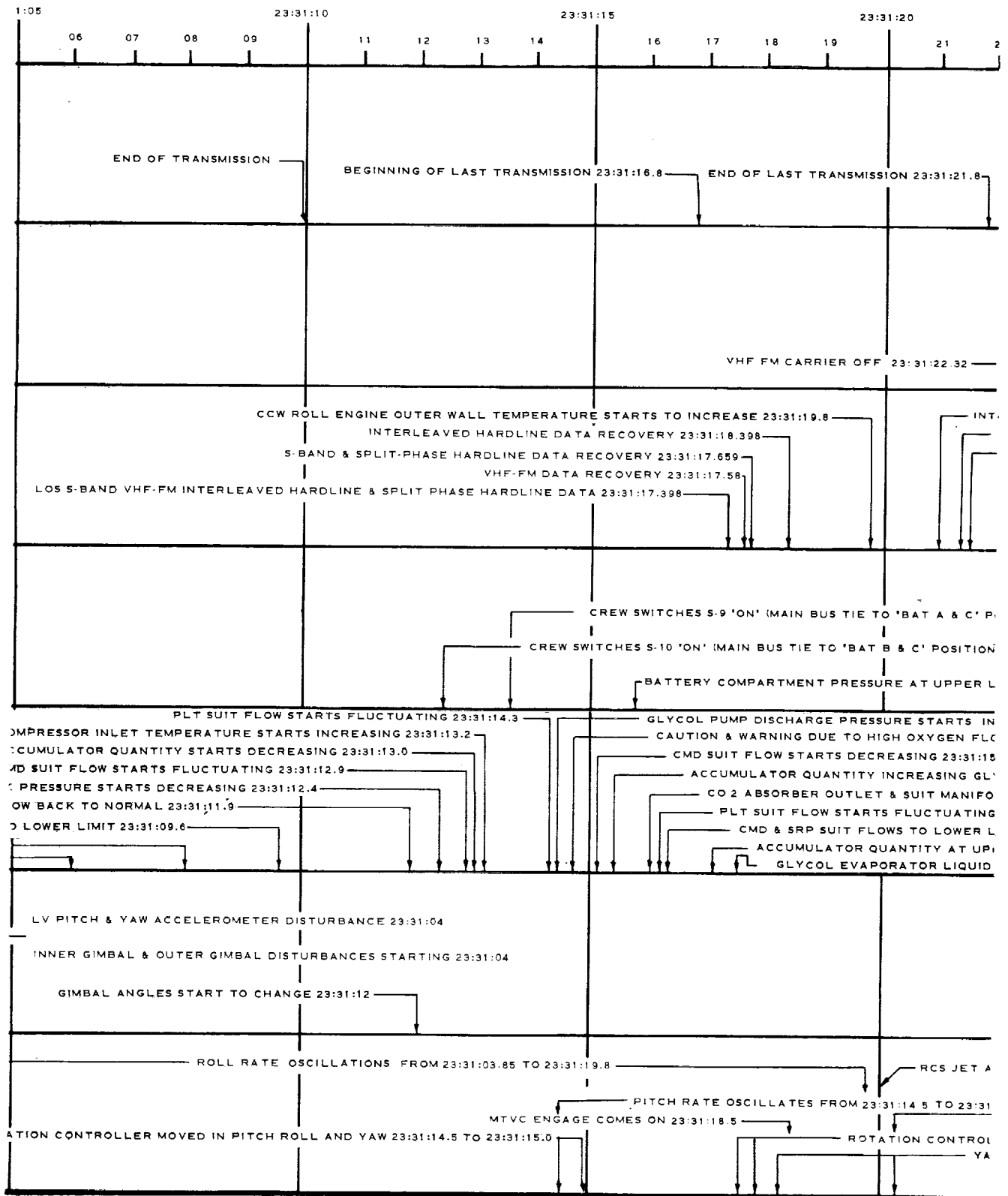
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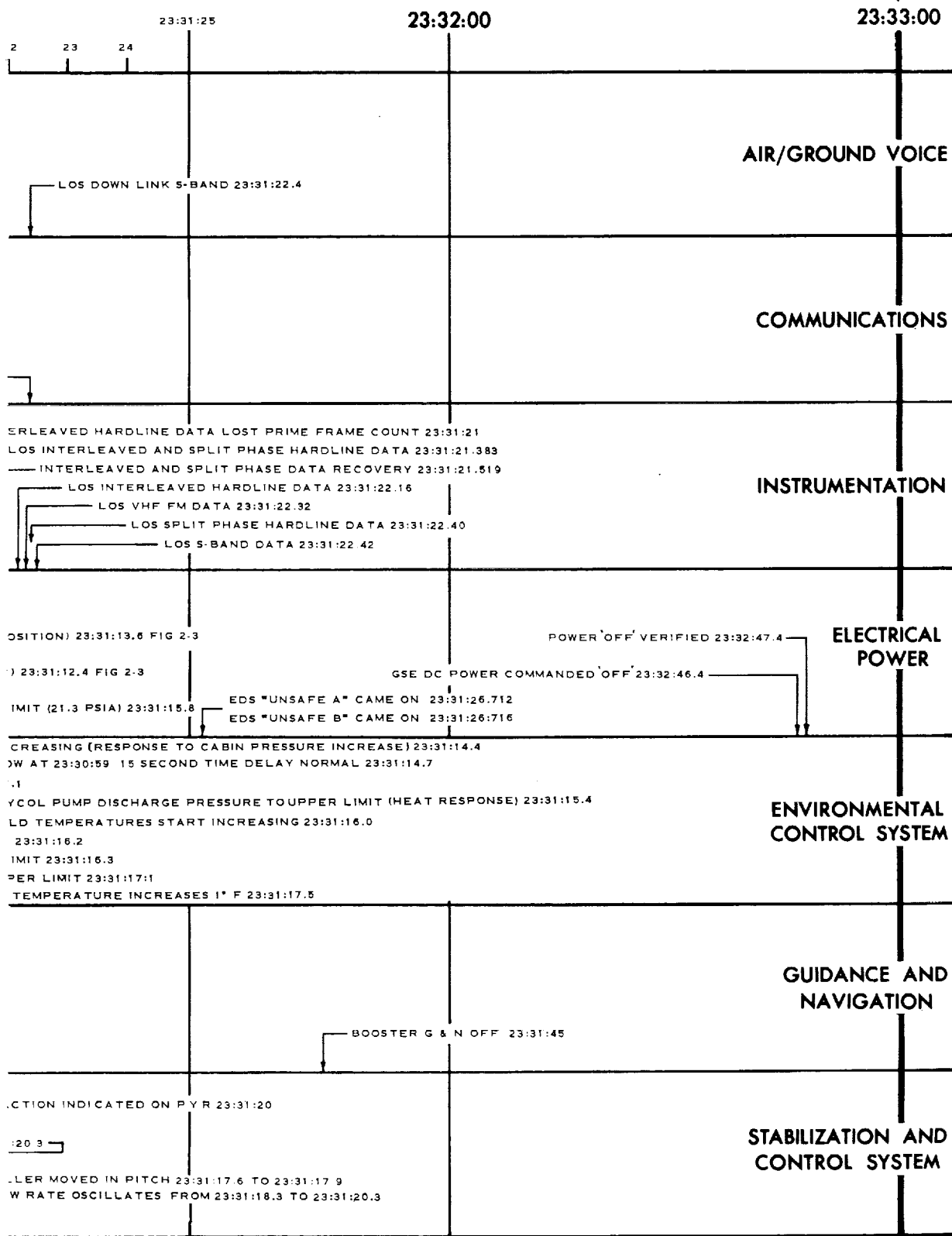
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RATE OF THE SPECIFIC MEASUREMENT

FIVE



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# SECOND SCALE



SEQUENCE OF EVENTS

**PART V**

**INVESTIGATION  
AND  
ANALYSIS**

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## PART V. INVESTIGATION AND ANALYSES

### 1. INSPECTION AND DISASSEMBLY

Immediately after the accident additional security personnel were positioned at Launch Complex 34 and the Complex was impounded. Prior to disturbing any evidence numerous external and internal photographs were taken of the spacecraft. After crew removal, two experts entered the Command Module to verify switch positions. Small groups of NASA and North American Aviation management, Apollo 204 Review Board Members, Representatives and Consultants inspected the exterior of Spacecraft 012. On January 28, 1967 an astronaut entered the Command Module to verify additional switch positions needed to clarify data.

The Board established procedures for disassembly of Spacecraft 012. The first step of disassembly was to establish safe working conditions at the spacecraft. This was accomplished by: (1) removal of the Launch Escape System, (2) removal of safetizing of all pyrotechnics, (3) examination of spacecraft structure for integrity, (4) examination of all pressure vessels for potential hazards, and (5) sampling of spacecraft atmosphere for harmful contaminants. After safe working conditions were established disassembly proceeded. A series of close-up stereo photographs of the Command Module was taken to document the as-found condition of the spacecraft systems.

The task of searching the physical evidence was difficult and time-consuming because of the small entrance and confined area of the Command Module. In order to remove the components as quickly as possible, two persons at a time were permitted to enter the Command Module for component removal. After the removal of each component, photographs were taken of the exposed area. This step-by-step photography was used throughout the disassembly of the spacecraft (Enclosures 1 through 11). Approximately 5000 photographs were taken.

After the couches were removed, a special false floor with removable 18-inch transparent squares was suspended from the existing couch strut fittings to provide access to the entire inside of the Command Module without disturbing evidence (Enclosure 12). A detailed inspection of the spacecraft interior was then performed followed by the preparation and approval by the Board of a Command Module disassembly plan. Command Module 014 was shipped to KSC on February 1, 1967 to assist the Apollo 204 Review Board in the investigation. This Command Module was placed in the Pyrotechnics Installation Building and was used to develop disassembly techniques for selected components prior to their removal from Command Module 012.

By February 7, 1967 the disassembly plan was fully operational. The concentrated effort of organized and coordinated component removal continued on a three-shift seven-day-a-week basis. All suspect circumstances or conditions were brought to the attention of the Apollo 204 Review Board.

All interfaces such as electrical connectors, tubing joints, physical mounting of components, etc. were closely inspected and photographed immediately prior to, during and after disassembly. Each item removed from the Command Module was appropriately tagged, sealed in clean plastic containers and transported under the required security to bonded storage (Enclosure 13).

On February 17, 1967 the Board decided that removal and wiring tests had progressed to a point which allowed moving the Command Module without disturbing evidence. The Command Module was moved to the Pyrotechnics Installation Building at KSC where better working conditions were available.

With improved working conditions, it was found that a work schedule of two eight-hour shifts per day for six days a week was sufficient to keep pace with the analysis and disassembly planning. The only exception to this was a three-day period of three eight-hour shifts per day used to remove the aft heat shield, move the Command Module to a more convenient work station and remove the crew compartment heat shield (Enclosure 14 and 15). The disassembly of the Command Module was completed on March 27, 1967.

From the beginning of disassembly, action was taken to catalog and place on display the hundreds of items that would be removed from the Command Module. The Pyrotechnics Installation Building was assigned to the Board for this purpose. A bonded storage room was established to receive and catalog components as they were removed. Command Module components were then displayed in a bonded area. The purpose of this area was to permit investigators to make visual examination of Command Module components (Enclosure 16). During the course of the disassembly over 1000 items were removed from the Command Module. A list of all removed components was maintained and distributed weekly to the Board. This list identified the location of components in the Pyrotechnics Installation Building as well as those undergoing further analyses and tests at other locations.

Throughout the disassembly operation, experts meticulously studied the exposed portions of the Command Module. The relative consumption of combustibles and sooting patterns were studied for clues as to the site of the ignition source. All structural elements, covers and panels were examined for evidence of association with the ignition. Component systems and parts were studied inch by inch with magnifying glasses and frequently parts were taken into the laboratory for microscopic or metallurgical analyses. Wire bundles were given particular attention and after separation, the individual wires were examined under 7 power magnification for sites of possible arcing.

All components that showed evidence of abnormal fire effects were examined internally and many were tested for functionality. Many components showed burning of internal insulation or potting material but in all cases they were exonerated on the basis of direction of flame travel or on the basis that there could be no communication with combustibles outside the component. Particularly suspect components were disassembled for detailed examination and analyses. All of the data developed by these visual and laboratory examinations were coordinated in making the final analysis as to probable ignition sources.

## 2. CHRONOLOGY OF THE FIRE

It is most likely that the fire began in the lower forward portion of the left-hand equipment bay. This would place the origin to the left of the Command Pilot, and considerably below the level of his couch.

Once initiated, the fire burned in three stages. The first stage with its associated rapid temperature rise and increase in cabin pressure, terminated approximately 15 seconds after the verbal report of fire. At this time (about 23:31:19 GMT) the pressure vessel, which constitutes the Command Module cabin, ruptured. During this first stage of the fire, flames moved rapidly from the point of ignition, traveling along the Raschel net debris traps which were installed in the Command Module to prevent items from dropping into equipment areas during tests or flight. At the same time, Velcro strips positioned near the ignition point also burned.

Based upon pressure and temperature measurements taken during the fire, the fire was not intense until about 23:31:12 GMT. The slow rate of buildup of the fire during the early portion of the first stage is consistent with the view that ignition occurred in a zone containing little combustible material. The slow rise of pressure could also result from absorption of most of the heat by the aluminum structure of the Command Module. The original flames rose vertically and then spread out across the cabin ceiling. The debris traps provided not only combustible material and a path for the spread of the flames but also firebrands of burning molten nylon. The scattering of these firebrands contributed to the spread of the flames.

By 23:31:12 GMT the fire had broken from its point of origin. Evidence is strong that a wall of flames extended along the left wall of the module, preventing the Command Pilot, occupying the left hand couch from reaching the valve which would vent the Command Module to the outside atmosphere. Although operation of this valve, located on a shelf above the left hand equipment bay, is the first step in established emergency egress procedures, such action would have been to no avail because the venting capacity was insufficient to prevent the rapid build-up of pressure due to the fire. It is estimated that opening the valve would have delayed Command Module rupture by less than one second.

Emergency procedures called for the Senior Pilot, occupying the center couch, to unlatch and remove the hatch while retaining his harness buckled. A number of witnesses who observed the television picture of the Command Module hatch window during this stage of the fire discerned motion that suggests that the Senior Pilot was reaching for the inner hatch handle. The Senior Pilot's harness buckle was found unopened after the fire indicating that he initiated the standard hatch opening procedure. Data from the Guidance and Navigation System indicate considerable activity within the Command Module after the fire was discovered. This activity is consistent with movement of the crew prompted by proximity of the fire or with the undertaking of standard emergency egress procedures.

The Command Module is designed to withstand an internal pressure of approximately 13 pounds per square inch above external pressure without rupturing. Data recorded during the fire show that this design criteria was exceeded late in the first stage of the fire and that rupture occurred at about 23:31:19 GMT. The point of rupture was where the floor or aft bulkhead of the Command Module joins the wall, essentially opposite the point of origin of the fire. About three seconds before rupture, the final crew communication began at 23:31:16.8 GMT. This communication ended shortly after rupture at 23:31:21.8 GMT (a detailed discussion of the two voice transmissions during the fire is given in a subsequent section).

Rupture of the Command Module marked the beginning of the brief second stage of the fire. This stage is characterized by the period of greatest conflagration due to the forced convection that resulted from the outrush of gases through the rupture in the pressure vessel. The swirling flow scattered firebrands throughout the crew compartment spreading the fire. This stage of the fire ended at approximately 23:31:25 GMT. Evidence that the fire spread from the left hand side of the Command Module toward the rupture area was found on subsequent examination of the module. For example, the leg rest control handle on the left side of the left hand couch is fabricated from aluminum tubing. Tongues of flame pouring over the control handle melted its left side. However, a nylon button at the base of the handle was unconsumed and only slightly deformed. Similarly, flames spreading across the floor beneath the couches caused more burning on the left side of three nylon helmet covers than on the right. The underside of the couches above the helmet covers was relatively unsooted. A lack of soot indicates a fire of only short duration beneath the couches some time after the couch structure had become heated. Further, storage boxes situated on the floor were damaged only slightly. Fire across the floor of the spacecraft lasted but a few seconds and spread from left to right.

Damage to the crew suits is also indicative of the spread of the fire from left to right. The Command Pilot's suit was damaged worst while the Senior Pilot's and Pilot's suits sustained progressively less damage.

Evidence of the intensity of the fire includes burst and burned aluminum tubes in the oxygen and coolant systems at floor level.

The pressure in the Command Module is estimated to have dropped to atmospheric pressure five or six seconds after rupture. The third and final stage of the fire began at about 23:31:25 GMT.

The third stage was characterized by rapid production of high concentrations of carbon monoxide. Following the loss of pressure in the Command Module and with fire now throughout the crew compartment, the remaining atmosphere quickly became deficient in oxygen so that it could not sup-

port continued combustion. Unlike the earlier stages where the flame was relatively smokeless, heavy smoke now formed and large amounts of soot were deposited on most spacecraft interior surfaces as they cooled. The third stage of the fire could not have lasted more than a few seconds because of the rapid depletion of oxygen. It is estimated that the Command Module atmosphere was lethal by 23:31:30 GMT, five seconds after the start of the third stage.

Although most of the fire inside the Command Module became extinguished shortly because of lack of oxygen, a localized, intense fire lingered in the area of the Environmental Control Unit. This unit is located in the left hand equipment bay, near the point where the fire is believed to have started. Failed oxygen and water/glycol lines in this area continued to supply oxygen and fuel to support the localized fire that melted the aft bulkhead and burned adjacent portions of the inner surface of the Command Module heat shield.

The loss of telemetry data at 23:31:22.4 GMT during the second phase of the fire makes determination of precise times of subsequent occurrences impossible. Thus all further times are based on less precise evidence such as entries in logs maintained by personnel monitoring various facets of the activity, review of voice tapes maintained of conversations between the Pad Leader and blockhouse monitors, and where so indicated, witness estimates.

### 3. DATA ANALYSES

#### a. SCOPE OF INVESTIGATION

All data have been analyzed by the panels and the Board with frequent help from consultants and outside specialist groups. Specific tests of Spacecraft 012 equipment were initiated on approval by the Board where results would contribute to an understanding of the cause of the accident.

A summary of these results follows.

#### b. ANALYSES OF RELEVANT TIME LINES

Enclosure 17 displays significant data that were obtained just prior to the report of the fire by the astronaut crew. These time lines cover the period of one minute before the fire report until all data signals were lost. The data shown includes signals from the gas chromatograph channel, the voltage of the AC bus 2, the C-band beacon, the VHF telemetry carrier, the flow of oxygen into the suit loop, various indicators of spacecraft motion, the biomedical data from the Senior Pilot, and audio signals (voice and noise) received on the S-band communication link. An analysis of each item and a summary of their correlation follows.

##### (1) Gas Chromatograph Telemetry Data Anomaly

The gas chromatograph was not installed for the Plugs Out Test and the connector that carried the telemetry data signals and the required AC power was open ended and was placed on the gas chromatograph shelf prior to the test. Power to the AC line in the connector was turned on during the test as required by the test plan.

A careful examination of the data records disclosed activity on this channel eight times up to and including the activity shown at approximately 23:30:50 GMT. Subsequent testing has demonstrated that the telemetry data lead in the connector has the characteristics of an antenna, and consequently can detect changes in electromagnetic fields within the spacecraft. Movement of this cable within a constant electromagnetic field will also produce signals of the magnitude observed during the Spacecraft 012 accident.

The disturbance at approximately 23:30:50 GMT indicates that such a change in the electromagnetic field took place. This change could have resulted from movement of the



connector. Evidence indicates that although the connector was not in its originally stored position after the accident, it probably was there during the initial stages of the fire.

## (2) AC Bus 2 Voltage Anomaly

A momentary increase in AC bus 2 voltage on all three phases was noted at approximately 9 seconds before the report of fire, and at the same time telemetry data from equipment powered from AC bus 2 showed abnormalities. These were:

1. Dropout of C-band decoder and transmitter outputs for 1.7 seconds.
2. Momentary dropout of VHF-FM transmitter.
3. Fluctuation of rotation controller null outputs.
4. Gas chromatograph telemetry signal transient. Other equipment connected to AC bus 2 at this time had no data monitoring capability that would detect effects of power transients.

The power distribution system was in the standard configuration at the time of the anomaly. DC bus A was receiving power from the ground DC "A" power supply. This power supply in turn powered AC bus 1 through inverter no. 1. Similarly DC bus B received power from the DC "B" power supply and powered AC bus 2 through inverter no. 2.

A possible explanation for dropout of the C-band decoder and transmitter, the interruption of the VHF-FM transmitter and rise in AC bus 2 voltage follows. The post-landing bus supplies power through a single conductor and circuit breaker to the power relay holding coils for both the C-band beacon and the VHF-FM transmitter. Temporary loss of voltage to the relay holding coils by unknown cause, would temporarily interrupt power to the C-band decoder and VHF-FM transmitter. The resulting transient to the voltage level on AC bus 2 could account for other measured phenomena.

The most probable cause of the AC bus 2 transient and associated indications was a momentary short or interruption of DC bus B. Analyses and subsequent testing correlate with this conclusion as follows:

### (a) AC Bus Transient

This high voltage indication can be interpreted as evidence of a momentary drop of DC voltage input to the inverter which results in a drop in AC output and a subsequent overshoot upon recovery. First indication of a disturbance was noted during apparent recovery. The voltage decrease was not seen because the channel was sampled only ten times a second.

### (b) C-band Beacon Dropout

The 1.7 second dropout observed is the minimum recovery time of the protective circuit internal to the beacon. A momentary interruption of AC bus 2 power for a period as short as 10 milliseconds would cause the C-band beacon dropout. These results were verified by special tests on a C-band beacon similar to the one used in Spacecraft 012. The most probable cause of the beacon dropout was a momentary loss of AC input power to the beacon particularly since the transponder dropout was coincident with a transient on the AC 2 bus and the beacon performed normally after recovery from the dropout until loss of data.

### (c) VHF-FM Transmitter Signal Dropout

The RF carrier dropout was observed by all monitoring ground stations and the duration of the dropout was approximately 20 milliseconds. The recorded data wave train from the VHF-FM transmitter also indicated dropout. A dropout of this nature has been duplicated by several special tests with a similar transmitter under similar conditions. Because the VHF transmitter recovered, the most probable cause of the dropout was a momentary interruption of the AC input power.

### (d) Rotation Controller Null Output Transients

Momentary transients were noted on each of the three control axes. The rotation controller, whose output was reading slightly off null just prior to the anomaly (the controller was pinned), was supplied by phase A of AC bus 2. Transient voltages on the

phase A bus would most likely be detected on the controller output. Special tests have shown that the null output transients experienced can be duplicated by a momentary interruption of AC bus 2 phase power.

(e) Gas Chromatograph Telemetry Signal Transient

As previously discussed this transient could result from a change in the electromagnetic field. Such a change in the electromagnetic field could also be the result of electric arcing.

(3) Anomalies in Oxygen Flow

Enclosure 18 is a schematic of the suit loop. Oxygen is normally supplied from the surge tank and the service module cryogenic storage tanks through an oxygen regulator which controls the supply pressure to approximately 100 psig. An oxygen flow transducer is installed in the supply line downstream of the oxygen regulator and oxygen is supplied to the suit loop through a demand regulator. The oxygen in the suit loop is circulated to the three astronauts through three separate branches. Each branch has an individual flow rate transducer.

The flow rate of oxygen started to increase approximately 40 seconds before the reported fire. The output limit or saturation of the flow transducer, which corresponds to a flow of 1.033 pounds per hour, was reached approximately 5 seconds before the first fire report. The oxygen flow transducer stayed in this saturated condition until loss of data occurred. The Caution and Warning Alarm was actuated 15 seconds after the oxygen flow exceeded one pound per hour. This delay is normal and prevents actuation of the Caution and Warning Alarm during normal short duration, high flow conditions.

The stable oxygen surge tank pressure, coupled with the normal oxygen regulated pressure, indicates that oxygen flow rate was not greater than 3 to 6 pounds per hour until approximately 7 seconds after the first fire report. Beyond that time the oxygen flow rate was much higher.

The initial flow rate increase is probably due to crew movement which normally results in increased leakage to the cabin at low differential pressure conditions. Enclosure 19 shows that at approximately 23:31:03 GMT the oxygen flow had increased to the suit loop to the extent that the pressure differentials across the suits and compressor were increasing. There was an indication that suit circuit flow through the Senior Pilot's suit was interrupted for about two seconds at approximately 23:31:09 GMT. This interruption further increased the pressure differentials in the circuit. The interruption in flow to the Senior Pilot's suit is not completely understood; however, it probably was caused by manipulation of the suit hoses or associated controls.

(4) Indications of Spacecraft Motion

A number of individual signals were received which are indicative of slight motions of the spacecraft within the last minute prior to the first fire report. These signals were of a random nature and are similar to signals that were obtained from the spacecraft during known crew movement.

These signals included corrective torque signals to the gyrocompasses in the Inertial Measuring Unit, a brushing or tapping of the Command Pilot's live microphone, the previously mentioned increase in oxygen flow attributed to suit leakage and an increase in the attention level of the Senior Pilot most noticeable between 23:30:30 GMT and 23:30:45 GMT. The Senior Pilot was the only member of the crew from whom biomedical data were recorded.

The nature of activity of the crew during this period could not be determined.

(5) S-Band Transmissions

There were no voice transmissions from the spacecraft from 23:30:14 GMT until the first indication of fire in the spacecraft by the crew. During this time the Command Pilot had a live microphone condition as noted previously. Two voice transmissions were subsequently received. The first of these was the first indication of the existence of a fire by the crew.

(a) The Live Microphone Anomaly

Voice tape analyses and instrumentation data records show that a live microphone, constant-keying condition, existed from the Command Pilot position during a considerable portion of the final test period. This condition apparently did not exist beyond the first of the final two voice transmissions from the spacecraft.

Audio circuits are normally actuated by a crewman pressing his Push-to-Talk (PTT) button on the cobra cable or in the Command Pilot's case by pressing his controller PTT or his cobra cable PTT button (Enclosure 20). This action serves to ground the microphone amplifier in the individual crewman's audio panel as well as the diode gate in the audio center on the S-band audio output. These functions allow signals to modulate the S-band transmitter.

The problem has been isolated to the PTT or keying line that runs between the cobra cable, translation controller, Command Pilot audio control panel and the audio center. Crew attempts to isolate the problem were unsuccessful although the Command Pilot's cobra cable was absolved after troubleshooting. Subsequent testing has also failed to disclose the cause of this problem.

Power limitations and subsequent testing of this circuitry indicates that sufficient current cannot be carried by this keying circuitry for it to be considered a possible ignition source.

(b) Voice Transmissions

The final two voice transmissions were made on S-band. No voice communications on VHF were made from the spacecraft during this period. The first transmissions lasted from 23:31:04.7 GMT through 23:31:10 GMT and the second lasted from 23:31:16.8 GMT through 23:31:21.8 GMT. The tape recordings of these transmissions have been analyzed extensively and the results are presented subsequently.

(6) Cabin Pressure Rise

The cabin pressure for the period from first report of the fire through loss of signal is shown in Enclosure 21.

First indication by either the cabin pressure or battery compartment (open to the cabin) sensors of a pressure increase occurred at approximately 23:21:11 GMT or about 6 seconds after the crew first reported the fire. The pressure exceeded the range of these transducers, 17 pounds per square inch absolute (psia) for the cabin and 21 psia for the battery compartment transducers by 23:31:16 GMT. Data from this time until loss of signal were derived from the response of Guidance and Navigation equipment to the different pressure changes. The cabin ruptured at a time of about 23:31:19 GMT and at a pressure of at least 29 psia.

Rupture occurred in the +Y, -Z quadrant and the resulting jet of hot gases caused extensive damage to the exterior structure (Enclosures 22 through 25)

(7) Summary of Relevant Events

Between 30 and 45 seconds prior to the report of fire, both the Command Pilot and Senior Pilot were active. The nature and level of the activity remain unknown. Except for the transients in data measurements that occurred approximately 9 seconds prior to the report of the fire, there are no other identified relevant events that preceded the fire. It should be noted that these data transients and subsequent activity of the crew may as easily be associated with the result of the fire as with the cause.

The increase in oxygen flow to the suit loop prior to and immediately following the report of the fire and its effect on the pressure distribution within the suit loop is the result of normal demand regulator response to oxygen leaking from the circuit to the cabin. This is further compounded by the response of the regulator to the rise in cabin pressure.

### c. ANALYSES OF CREW VOICE TRANSMISSION DURING THE FIRE

The tape transcripts of the voice tapes from the Command Module during the period of the fire have been analyzed extensively. These analyses included a review of all transmissions prior to the fire that were made by the crew during the test in an attempt to aid in the determination of who made these last two transmissions and what was said. These analyses were made by NASA personnel familiar with the communication systems, the crew and their voice characteristics, the sequence of events before, during and after the fire as determined during the investigation. The Board also reviewed these transmissions. Experts at the Bell Telephone Laboratories performed extensive analyses of the tape record.

Except for a portion of the first transmission which is quite clear, the remainder of the transmissions is not clear and it is impossible to define exactly what was said by the crew.

Two points made by the Bell Telephone Laboratory experts should be noted:

1. The present state-of-the-art of analyses of voice records is such that little if anything can be determined as to what was said if the recording is not sufficiently clear to be intelligible by listening alone. Analyses can provide some clues as to who may have made the transmissions; however, these clues are not definitive.

2. When the recording of the transmission is not clear, there will be nearly as many interpretations of what was said as there are qualified listeners.

A summary of various interpretations of these transmissions is made in the following paragraphs.

The analysis of the first transmission is as follows:

This transmission began at 23:31:04.7 GMT with an exclamatory remark. This transmission is not clear. Listeners believe this initial remark was "Hey" or "Fire" but this is not certain.

Some listeners believe and laboratory analysis supports this belief that this transmission was made by the Command Pilot. This remark is followed by a short period of noise (bumping sound, etc.).

The second portion of this first transmission begins at 23:31:06.2 GMT with an unclear word. Most listeners believe the first word to be one of the following:

"I've"

"We've"

The remainder of this transmission is quite clear and is: "...Got a fire in the cockpit", followed by a clipped word sounding like "Vheh", which ended at 23:31:10 GMT. Many listeners believed this transmission was made by the Pilot and laboratory analyses tend to support this belief. However, no firm conclusion can be drawn.

The analysis of the second transmission is as follows:

Following a 6.8 second period of no transmission, the second transmission began at 23:31:16.8 GMT and ended at 23:31:21.8 GMT. The entire second transmission is garbled and is, therefore, subject to wide variation of interpretation as to content and as to who made the transmission and no definitive transcription is possible.

The general content of this transmission consists of what appears to be three separate phrases. It has been interpreted several ways by many listeners. The following is a list of some of the interpretations that have been made:

1. "They're fighting a bad fire - Let's get out ....Open 'er up."
2. "We've got a bad fire - Let's get out....We're burning up."
3. "I'm reporting a bad fire....I'm getting out...."

This transmission ended with a cry of pain. Some listeners believe this transmission was made by the Pilot.

It should be noted that:

1. The total duration of these two transmissions was brief, lasting 10.3 seconds; the first lasted 5.3 seconds and the second lasted 5.0 seconds, with a 6.8 second period of no transmission.

2. The transmissions provide evidence only of the time the crew first reported the existence of the fire and do not provide any direct information as to the cause of the fire.

#### d. MEDICAL ANALYSES

Loss of consciousness was due to cerebral hypoxia due to cardiac arrest resulting from myocardial hypoxia. Factors of temperature, pressure and environmental concentrations of carbon monoxide, carbon dioxide, oxygen and pulmonary irritants were changing extremely rapidly. It is impossible to integrate these variables on the basis of available information with the dynamic physiological and metabolic conditions they produced, in order to arrive at a precise statement of time when consciousness was lost and when death supervened. The combined effect of these environmental factors dramatically increased the lethal effect of any factor by itself. It is estimated that consciousness was lost between 15 and 30 seconds after the first suit failed. Chances of resuscitation decreased rapidly thereafter and were irrevocably lost within 4 minutes.

#### 4. CAUSE OF THE APOLLO 204 FIRE

The fire in Apollo 204 was most probably brought about by some minor malfunction or failure of equipment or wire insulation. This failure, which most likely will never be positively identified, initiated a sequence of events that culminated in the conflagration.

A great deal of effort has been expended in an attempt to find this specific initiator. Although unsuccessful in this search, this effort has produced a fairly good understanding of the types of things that may have been the initiator and the types of things that probably could not have been the initiator.

Electrostatic discharge, spontaneous combustion of flammable material, mechanically produced heat by machinery and heat from the impact of a struck object have been eliminated as reasonable possibilities of ignition of the fire. The flow of oxygen through orifices or metering valves can create heat through the excitation of resonating frequencies in the gas. However, a thorough examination of the hardware and evaluation of recorded performance of the equipment eliminates the energy of flowing oxygen as a possible initiator.

The most obvious source of energy needed to initiate the fire existed in the spacecraft's power distribution system. Current carrying wires were distributed throughout every major region of the Command Module. The most likely ways in which electrical power can initiate a fire are the following:

1. Through malfunction of the equipment being powered which in turn ignites or initiates a fire in nearby combustibles.
2. Overload in the conductor resulting from shorts in equipment or wiring. This overload will cause the conductor to overheat and ignite nearby combustibles (Enclosure 26).
3. Electric arcs that are created when the insulation is defeated between power carrying conductors and the spacecraft structure or equipment.

A large majority of the wires were left undamaged. However, there were a number of cases where exposed wire showed extensive burning, overheating or complete destruction. There were also several places where pitting of exposed conductors and adjacent structure indicate that an electric arc had occurred.

##### a. MALFUNCTION OF ELECTRICAL POWERED EQUIPMENT

After removal from the spacecraft, each component or subassembly was critically examined to determine whether or not it could be associated with the initiation of the fire. The vast

majority of these could be classified as non-initiators on the basis of external examination and recorded performance. If, however, there was any suspicion that an item was involved with the initiation of the fire, it was subjected to intensive scrutiny that involved one or more of the following procedures: Laboratory analysis of damage, electrical continuity and resistance tests, functional performance using established procedures for "bench checks" and careful disassembly which included repeating some of the above steps on individual parts of the assembly. The results of this effort led to the conclusion that none of the electrically powered spacecraft systems or subassemblies was associated with the initiation of the fire.

#### b. ELECTRICALLY OVERLOADED CONDUCTORS

The Apollo spacecraft wiring is protected with Teflon insulation. Teflon was chosen as the insulating material after a series of tests clearly showed that it was the least likely to burn when overheated by shorting. Individual conductors in a wire bundle using Teflon-insulated wires could be melted to destruction without initiating a sustained fire in the bundle when located in a 100-percent oxygen atmosphere at 5 psia. The Teflon-insulating material provided a high degree of fire protection to wire bundles which may contain electrically overloaded wires. Primary protection to wiring in the spacecraft, however, was provided by circuit breakers and fuses which protected all power-carrying conductors. Critical analyses of all circuit breaker installations showed that this protection was provided adequately with only a few exceptions. Several indications of shorted wiring were made the subject of individual detailed investigations. These investigations have all proved negative except for a few cases that could not be exonerated completely.

#### c. ELECTRIC ARCS

Teflon has excellent fire resistance but low resistance to cold flow. The Teflon covering on the wire used in Apollo 204 could be damaged easily or penetrated by abrasion. The covering could also be damaged when forced against the structure by poor installation. The Board found numerous examples in the wiring of poor installation, design and workmanship. (An example is shown in Enclosure 27 where a wrench socket was found in the spacecraft.) If a power conducting wire experiences penetration of its insulation by the metal structure of the spacecraft or spacecraft components, an instantaneous short to ground is created at the point of conductor contact. An arc or a series of arcs between conductor and structure results. The arcing action may be terminated by the blowing away of molten metal at the point of contact, or if sufficient mechanical pressure exists, fusion between the conductor and structure may occur to create a continuous short. The previous occurrence of an arc can be determined through examination of hardware because a characteristic pit or crater is left at the location of contact. Tests in a 16.5 psia oxygen atmosphere have shown that sparks blown from arcs can ignite combustible material several inches from the arc. Circuit breakers and other practical circuit interrupting devices cannot act rapidly enough to prevent an arc. Thus, arcs cannot be eliminated as a potential source of ignition energy. As noted previously, there were strong data indications of an abrupt, short-duration voltage decrease. This is consistent with a quickly terminated arc. During the examination of hardware and wiring, particular emphasis was placed on locating craters near power cables. While several such craters were found, only one appeared to be linked closely to the time of the fire by other supporting evidence. A complete investigation of the evidence associated with this possible ignition source has relegated it to a low probability. Studies of fire damage patterns indicate that the most likely region for the start of the fire is underneath the lithium hydroxide access door. Damage is so extensive in this location that the physical evidence remaining provides little interpretive information (Enclosure 11). Power cable insulation passing under this door was potentially vulnerable to abrasion from the corner along the lower edge of the door. (Enclosure 28 shows this cable as it is installed on Spacecraft 014.) If this cable were the cause, it cannot be proven since both the power cable and the inside edge of the door were completely destroyed. It is most probable that the fire was initiated by an electric arc either in this location or in some other region near the Environmental Control Unit. Other powered cables in the Environmental Control Unit may have been the source but extensive destruction of them precludes a positive determination. The time of initiation probably coincides with the spacecraft power interruption at 23:30:55 GMT.

The Board's investigation was facilitated by the wide application of simulation techniques. The consequences of several types of electrical faults were studied in this way. The most valuable simulation, however, employed full-scale fire tests in a boilerplate mock-up with combustibles arranged in the configuration of Command Module 012. These tests were conducted by MSC for the Board. Ignition was obtained by a hot wire in the general area in which ignition is suspected to have occurred in the fire and provisions were made for simulating rupture at proper time and location.

Total time of the fire and the pressure history reproduced those of the fire quite closely thus adding confidence to the deduced origin and mode of propagation of the fire. Such simulation techniques should be applied in examining the fire hazards of future spacecraft. They provide a reliable means of assessing fire hazards. They have also demonstrated that laboratory tests on small samples may give misleading results.

#### d. EFFECT OF COOLANT ON ELECTRICAL WIRES AND EQUIPMENT

The discussion of possible electric power distribution malfunctions in Apollo 204 cannot be complete without inclusion of the effect of Environmental Coolant System coolant leakages. The Apollo Block I Spacecraft uses RS-89 as a coolant. This coolant is a mixture of 62.5 percent ethylene glycol, 35.7 percent water, and 1.8 percent stabilizer and corrosion inhibitor. Although the mixture is not highly combustible, leakage and spillage of this fluid present a considerable fire hazard. The water evaporates more readily than the ethylene glycol and the inhibitor consists of two combustible salts which do not evaporate. Consequently, spilled coolant can become a dangerous combustible if it is not removed properly. The inhibitor mixture presents a second hazard in that it is also hygroscopic and electrically conductive. Thus, the residue from coolant that was spilled and subsequently evaporated, remained slightly wet. This residue is corrosive and may conduct electricity if it wets electrical wiring or equipment that does not have water-proof insulation. The conductive path so formed will progressively improve itself as dendrites grow through electrolytic action. The RS-89 coolant is particularly dangerous in the presence of damaged or improperly insulated electrical equipment and harnesses. During the design of Apollo Block I Spacecraft a decision was made to seal electrical components and connectors. As a result, many of the Spacecraft 012 electrical systems were watertight. (Block II Spacecraft are designed to have complete sealing of electrical equipment and harnesses.)

Coolant in the spacecraft is used to extract heat from the cabin atmosphere and from the circulation loop to the spacesuits. It also provides direct cooling through coldplates to numerous pieces of electrically powered equipment. Thus, the cooling system is extensive throughout the Command Module. The plumbing that carries the coolant is assembled from aluminum tubing utilizing both metallurgical (soldered, brazed or welded) and mechanical joints. Numerous plumbing joints are distributed throughout the spacecraft. It was found that the solder joints were improperly designed in that strength margins were inadequate to resist damage from unplanned loads. Such loads may result during equipment installation or when tubing is used as hand-holds or is bumped by technicians working in the Command Module. The result was that a number of leaks in solder joints were experienced during the history of all Block I spacecraft. The mechanical joints also had leakage problems.

There is no substantial evidence that coolant was involved in the initiation of the fire. However, this coolant, when spilled on damaged electrical wires and equipment, provides both the fuel and the ignition mechanism to start a fire. This has been demonstrated in laboratory tests.

#### e. SPACECRAFT ATMOSPHERE

The use of pure oxygen in American spacecraft has been the subject of much consideration. The use of a diluent gas, either nitrogen or helium, in large proportions would undoubtedly reduce the risk of fire to a significant degree. At the same time it would introduce other operational problems and risks. There is no obvious advantage of one diluent over the other, although much pro-

gress has been made in developing the complex technology required for controlling gas concentrations to maintain a proper mixture reliably. This technology is still far from being fully developed. Furthermore, there are many difficult operational problems that must be solved in a reliable manner in order to decrease rather than increase the risks before undertaking the use of a two gas system.

The desirable characteristics of a two gas system, however, should not be ignored. The development of technology that will warrant confidence in the use of such a system should be continued.

#### f. SUMMARY

Although the Board was not able to determine conclusively the specific initiator of the Apollo 204 fire, it has identified the conditions which led to the disaster. These conditions were:

1. A sealed cabin, pressurized with an oxygen atmosphere.
2. An extensive distribution of combustible materials in the cabin.
3. Vulnerable wiring carrying spacecraft power.
4. Vulnerable plumbing carrying a combustible and corrosive coolant.
5. Inadequate provisions for the crew to escape.
6. Inadequate provisions for rescue or medical assistance.

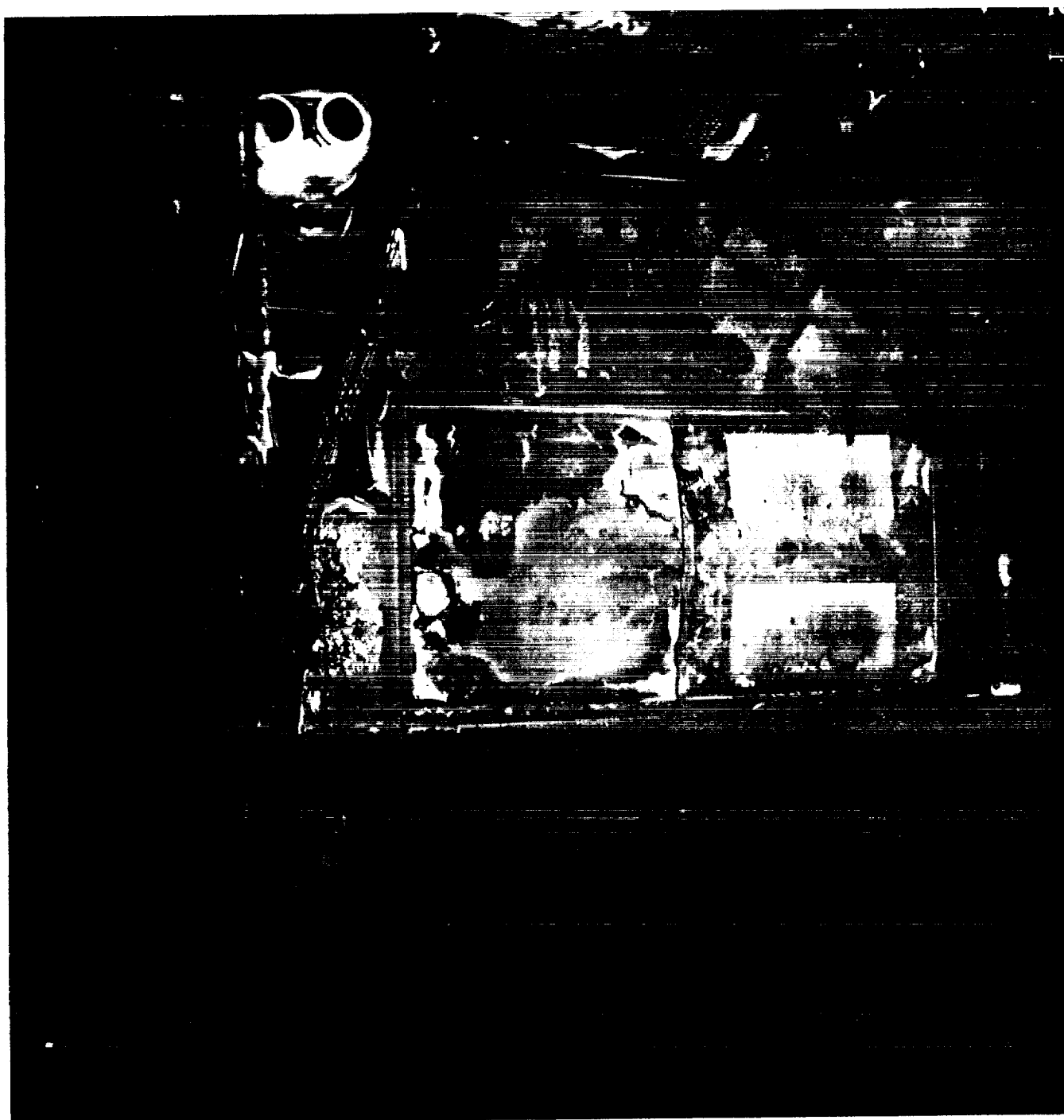
Having identified the conditions that led to the disaster, the Board addressed itself to the question of how these conditions came to exist. Careful consideration of this question leads the Board to the conclusion that in its devotion to the many difficult problems of space travel, the Apollo team failed to give adequate attention to certain mundane but equally vital questions of crew safety. The Board's investigation revealed many deficiencies in design and engineering, manufacture and quality control. When these deficiencies are corrected the overall reliability of the Apollo Program will be increased greatly.



## LIST OF ENCLOSURES

- V - 1      Photograph - Upper Left - hand Equipment Bay Above Environmental Control Unit.
- V - 2      Photograph - Upper Left - hand Forward Corner of Command Module Interior.
- V - 3      Photograph - Upper Right - hand Forward Corner of Command Module Interior.
- V - 4      Photograph - Right - hand Side of Forward Lower Equipment Bay.
- V - 5      Photograph - Gas Chromatograph Compartment in Lower Left - hand Side of Forward Equipment Bay (Cameras Laying in Compartment).
- V - 6      Photograph - Lower Left - hand Forward Corner of Command Module Interior.
- V - 7      Photograph - Command Module Floor Showing Helmet Covers and Lithium Hydroxide Canister Storage Box.
- V - 8      Photograph - Left Rear Corner of Command Module Floor.
- V - 9      Photograph - Command Module Electrical Panel Showing Isolated Fire Damage.
- V - 10      Photograph - Environmental Control Unit in Lower Left - hand Equipment Bay.
- V - 11      Photograph - Close - up of Failed Environmental Control Unit Tubing.
- V - 12      Photograph - Transparent False Floor Used During Disassembly.
- V - 13      Photograph - Bonded Storage Area.
- V - 14      Photograph - Aft and Crew Compartment Heat Shields After Removal.
- V - 15      Photograph - Command Module 012 in Final Disassembly Area.
- V - 16      Photograph - Bonded Area to Display of Removed Command Module Components.
- V - 17      Time Line of Significant Data.
- V - 18      Suit Circuit Simplified Schematic.
- V - 19      Graph Showing Suit Circuit Oxygen Flow Rates.
- V - 20      Schematic of Audio Push - to - Talk Circuits.
- V - 21      Time Line Cabin Pressure.
- V - 22      Drawing of Inner Face Sheet of Aft Bulkhead Showing Ruptured Areas.
- V - 23      Drawing of Outer Face Sheet of Aft Bulkhead Showing Ruptured Areas.
- V - 24      Photograph - Inner View of Aft Heat Shield Showing Damage.
- V - 25      Photograph - External View of Aft Bulkhead Showing Damage ( View from Bottom) .
- V - 26      Cut - away View of Command Module Showing Exposed Nonmetallic Materials.
- V - 27      Photograph - View of Socket Found Adjacent to Wire Bundles During Disassembly of Command Module 012.
- V - 28      Photograph - View of Wire Bundle in Command Module 014 Containing DC Power Leads Passing Over Tubing and Entering Environmental Control Unit. A Similar Arrangement Existed in Command Module 012.

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LEFT HAND FORWARD EQUIPMENT BAY

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ENCLOSURE V-1

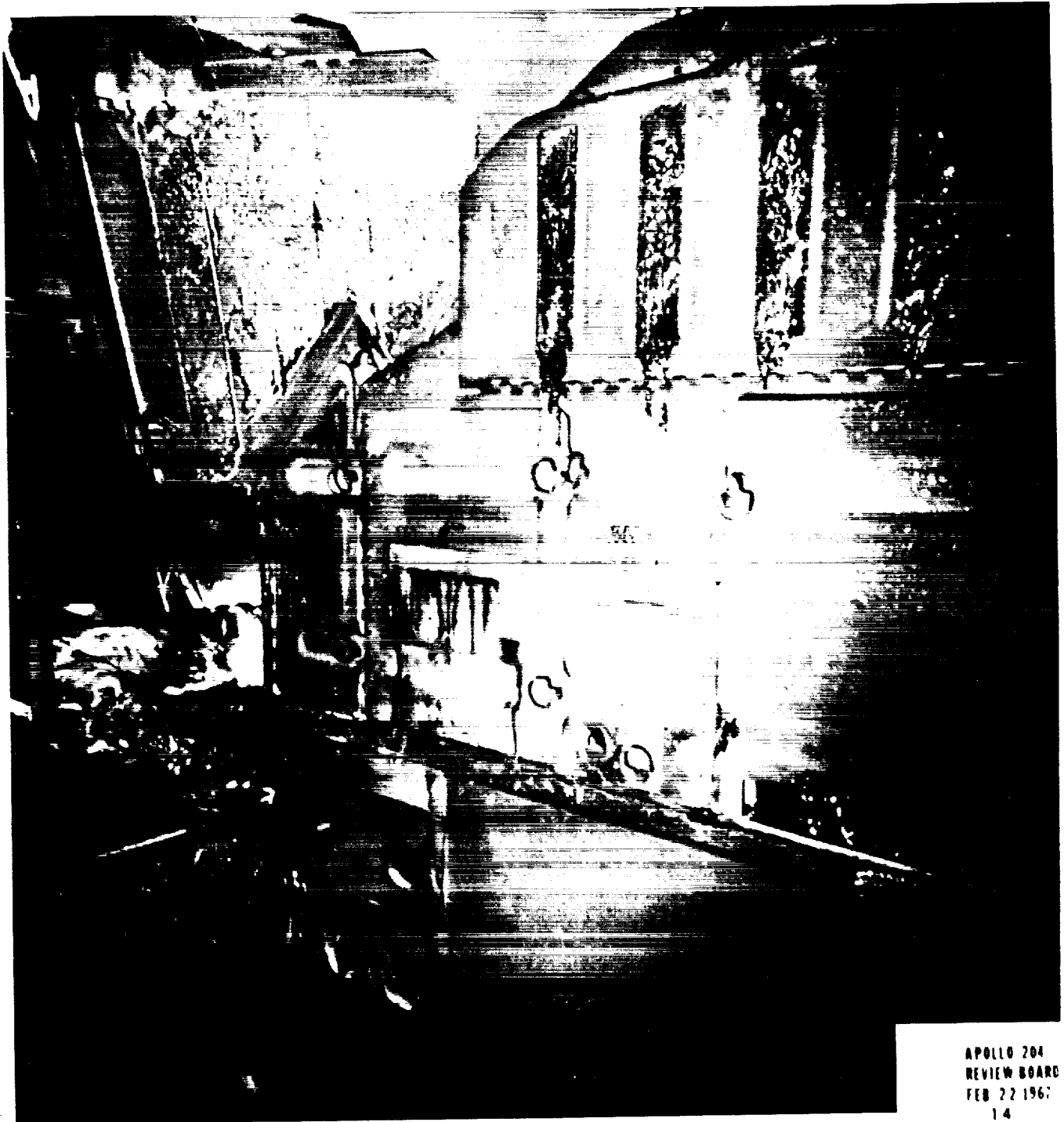
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EXTREME UPPER LEFT HAND CORNER BETWEEN LOWER EQUIPMENT BAY  
AND LEFT HAND EQUIPMENT BAY

ENCLOSURE V-2

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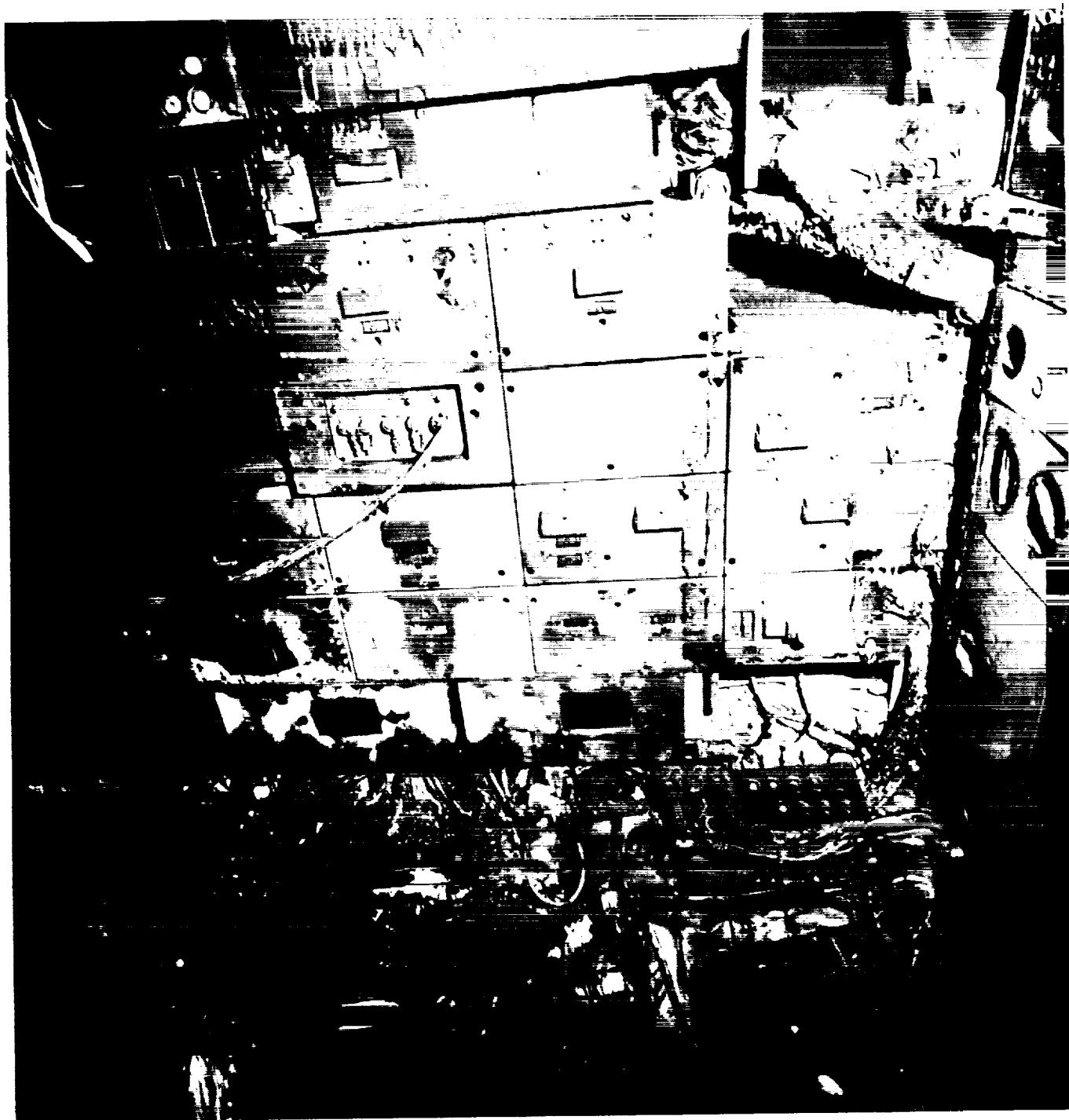


APOLLO 204  
REVIEW BOARD  
FEB 22 1967  
14

EXTREME RIGHT HAND CORNER ABOVE LOWER EQUIPMENT BAY AND RIGHT HAND EQUIPMENT BAY

ENCLOSURE V-3

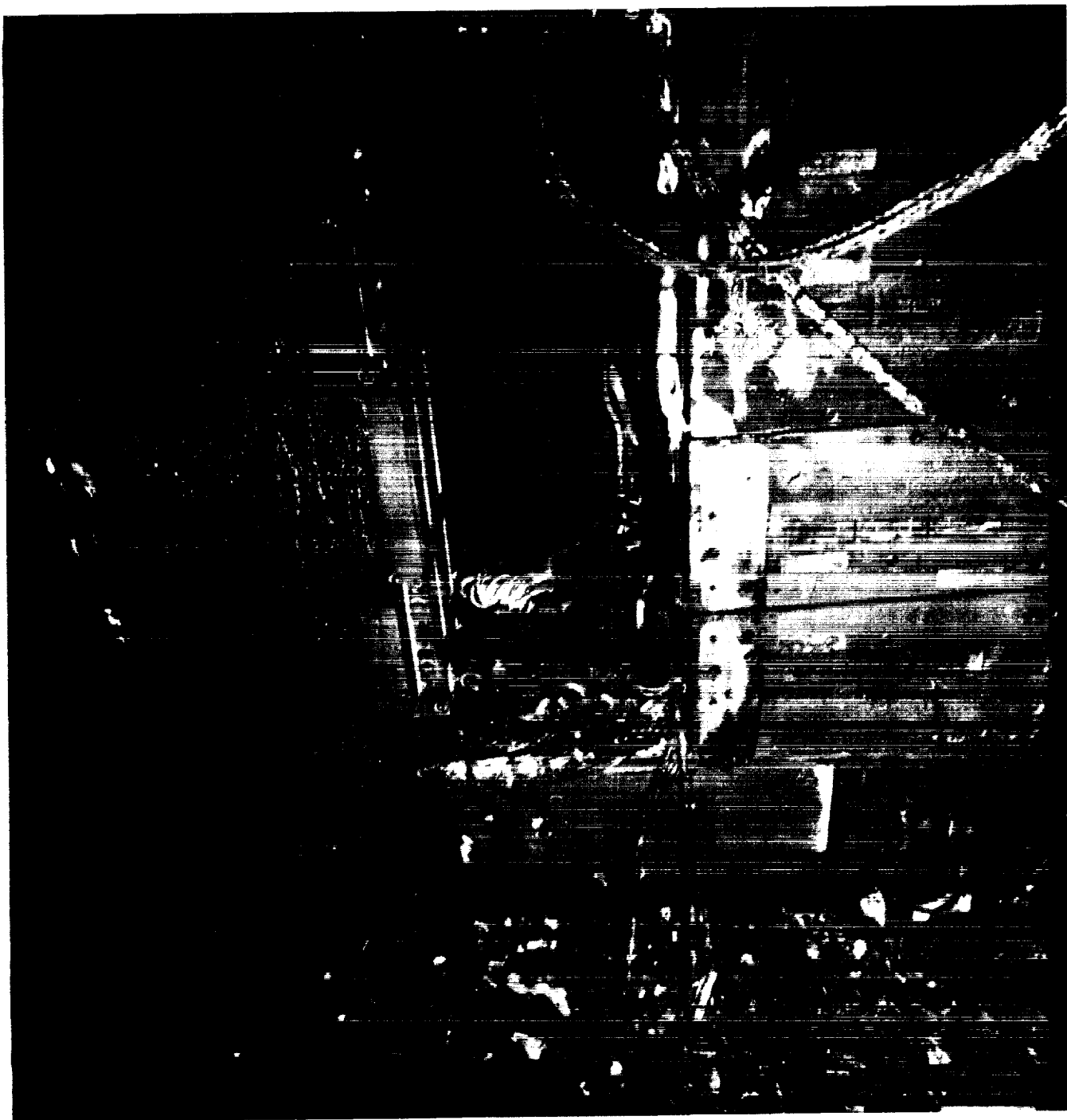
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RIGHT HAND SECTION OF LOWER EQUIPMENT BAY

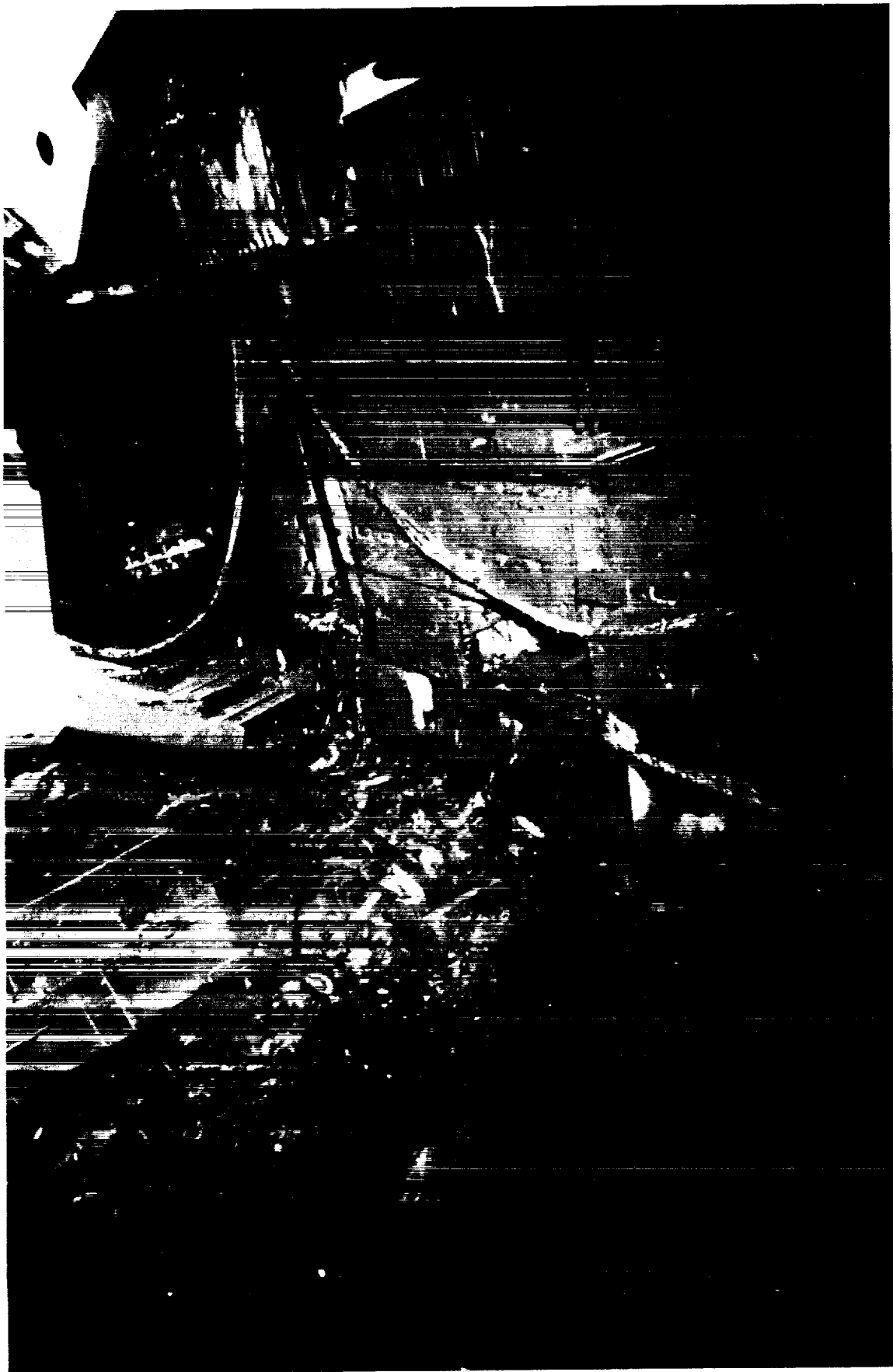
ENCLOSURE V-4

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LOWER LEFT HAND SECTION OF LOWER EQUIPMENT BAY

ENCLOSURE V - 5



VIEW OF FLOOR BELOW LOWER EQUIPMENT BAY  
ENCLOSURE V-6

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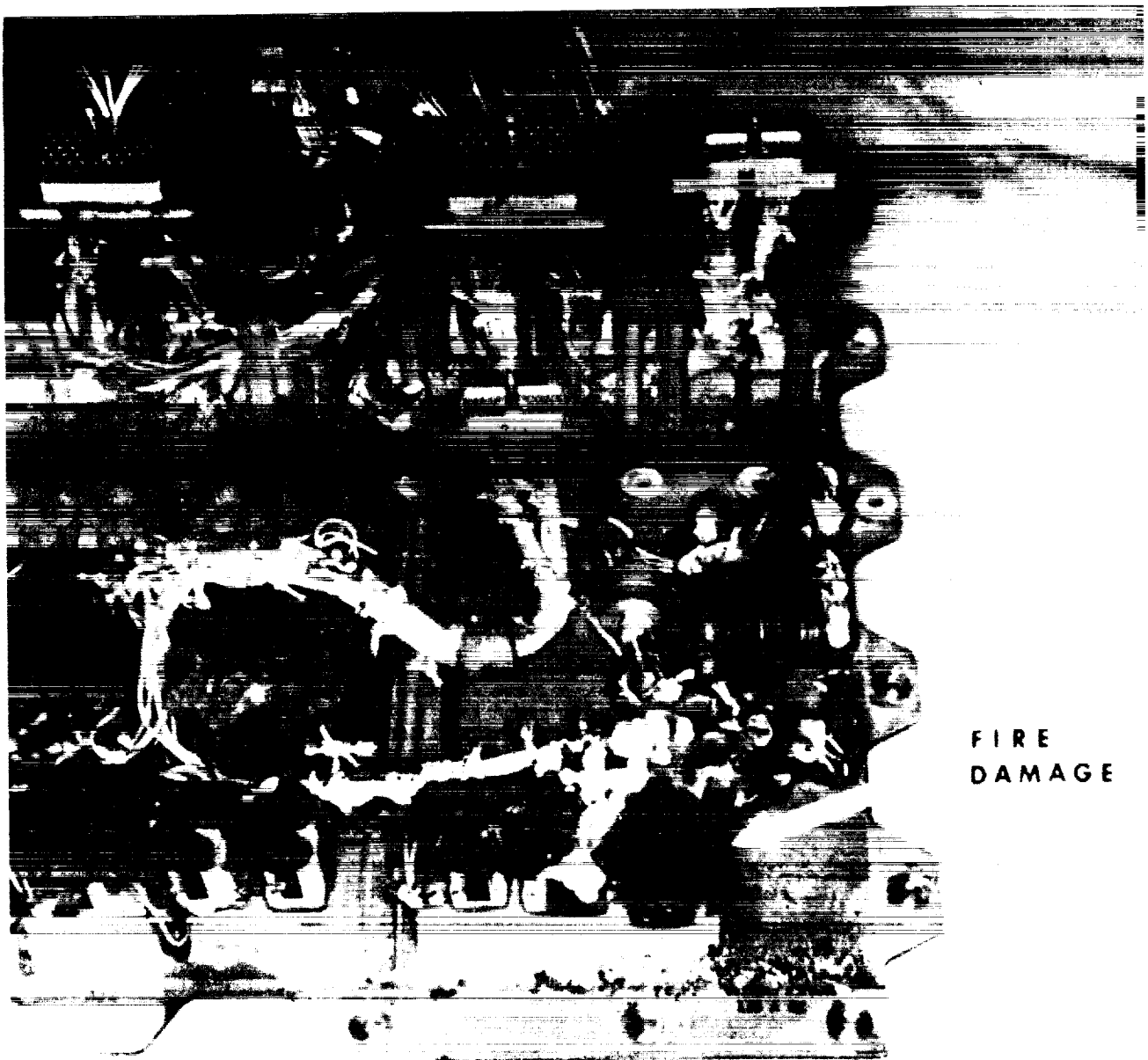
VIEW OF HELMET COVERS



VIEW OF HELMET COVERS

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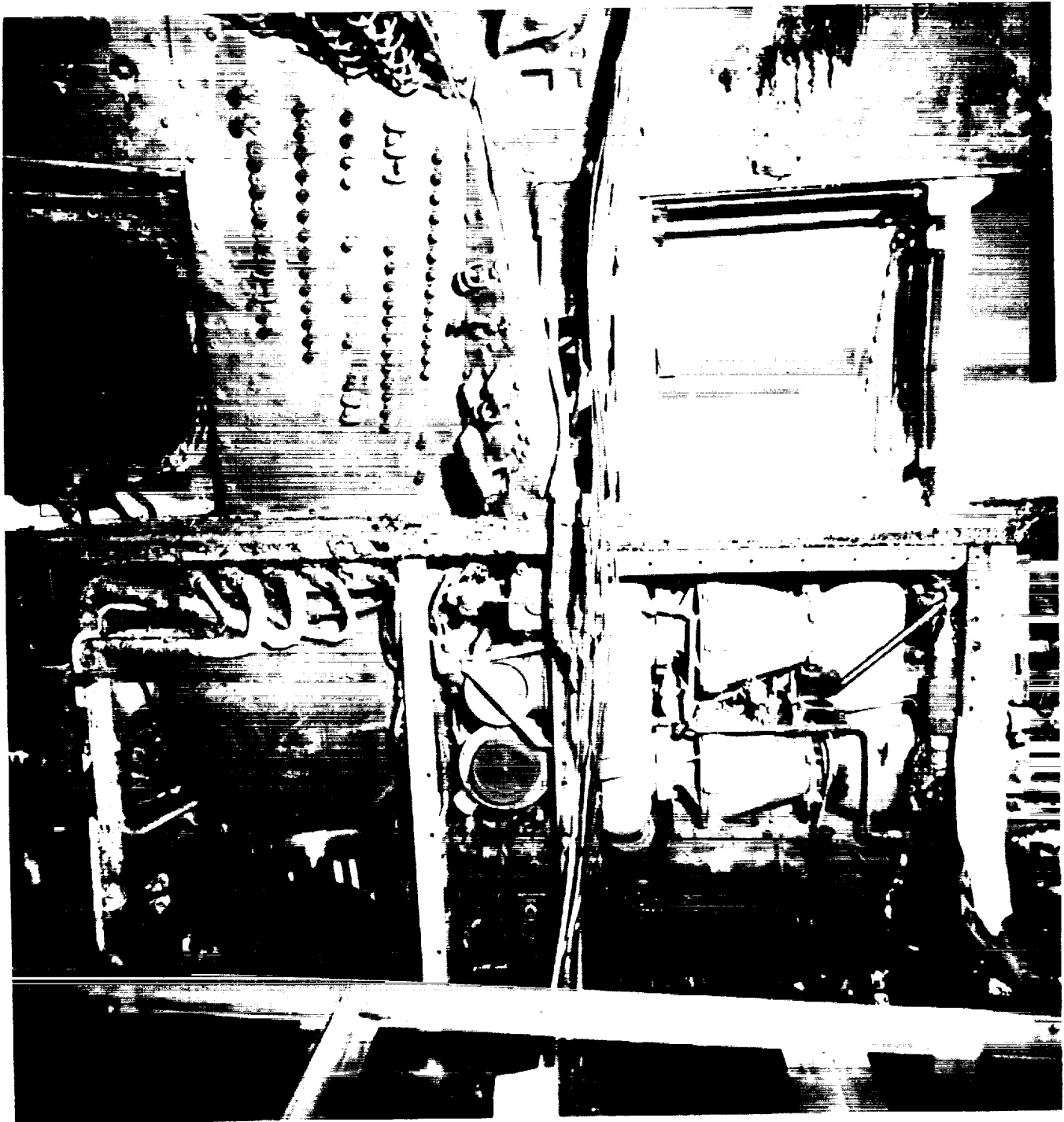
ENCLOSURE V - 8



INTERIOR VIEW OF PANEL 13 SHOWING DAMAGE NEAR THUMB WHEELS

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ENCLOSURE V-9



VIEW OF ENVIRONMENTAL CONTROL UNIT

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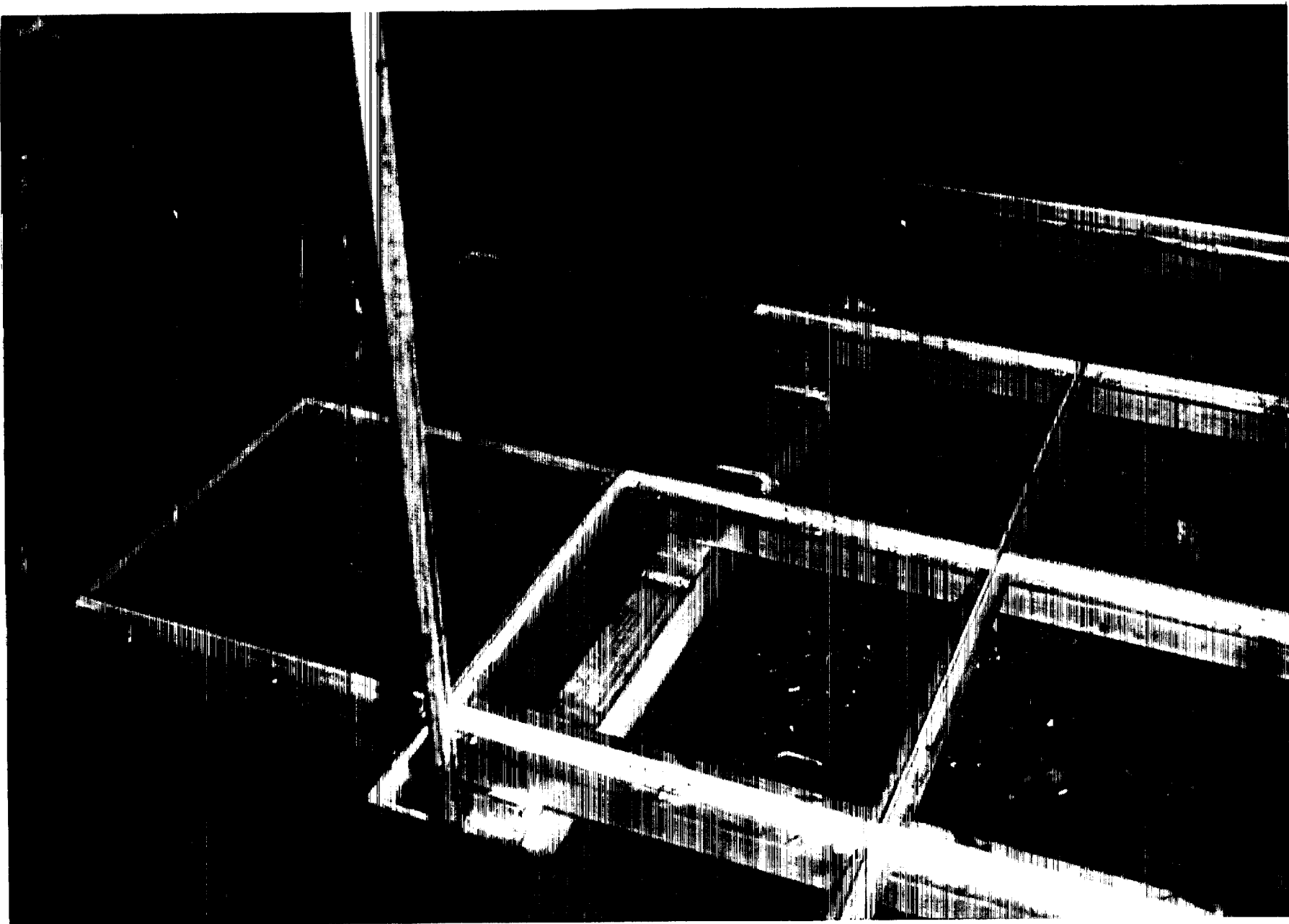
ENCLOSURE V-10



ENVIRONMENTAL CONTROL SYSTEM INSTRUMENTATION HARNESSES  
AFTER ACCIDENT

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ENCLOSURE V-11



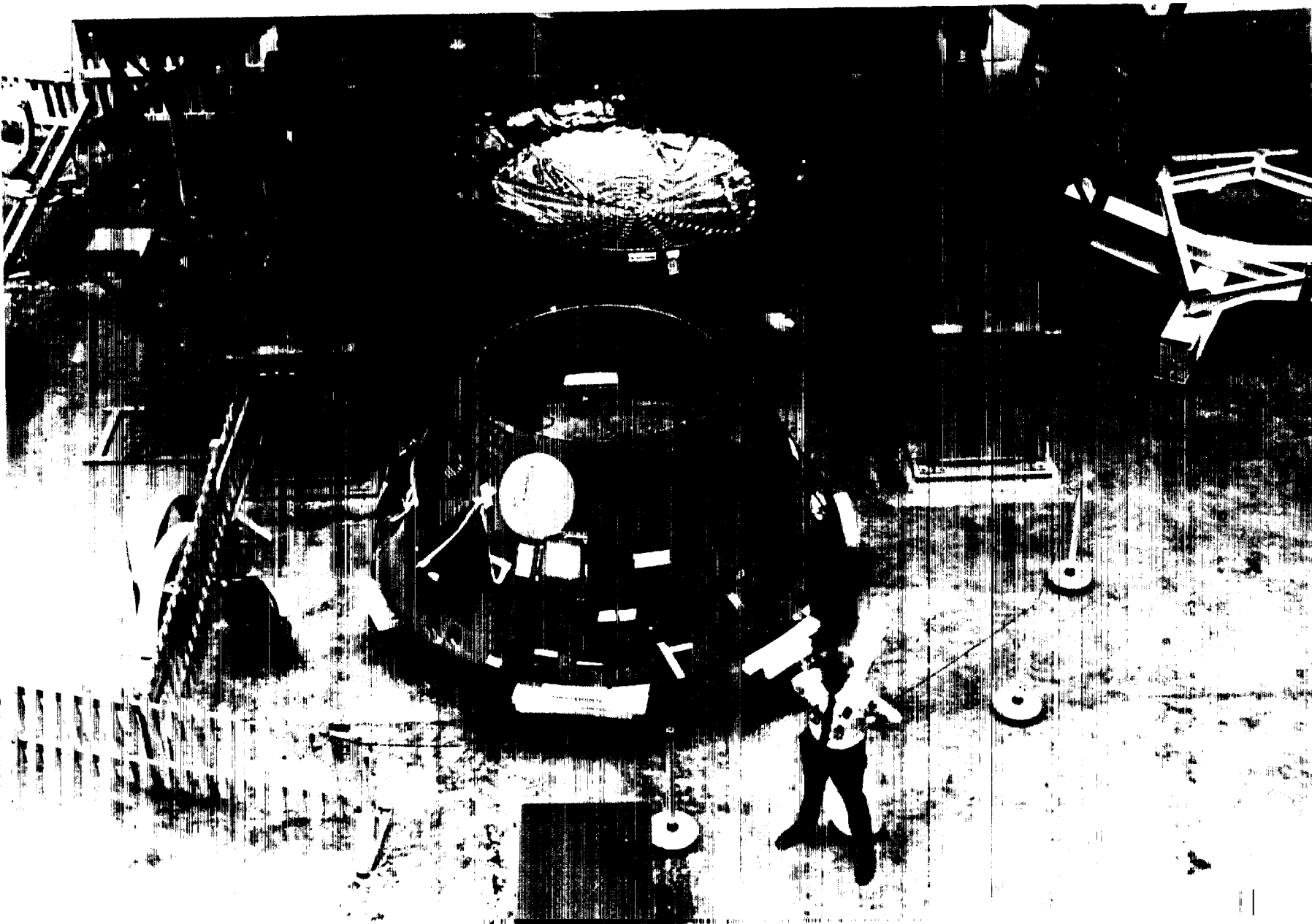
FALSE FLOOR INSTALLED IN SPACECRAFT 012

ENCLOSURE V - 12  
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PYROTECHNICS INSTALLATION BUILDING BOND ROOM, LOOKING TOWARD THE SOUTH WALL

ENCLOSURE V-13  
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AFT HEAT SHIELD IN ALIGNMENT FIXTURE WITH CREW COMPARTMENT  
HEAT SHIELD IN THE FOREGROUND

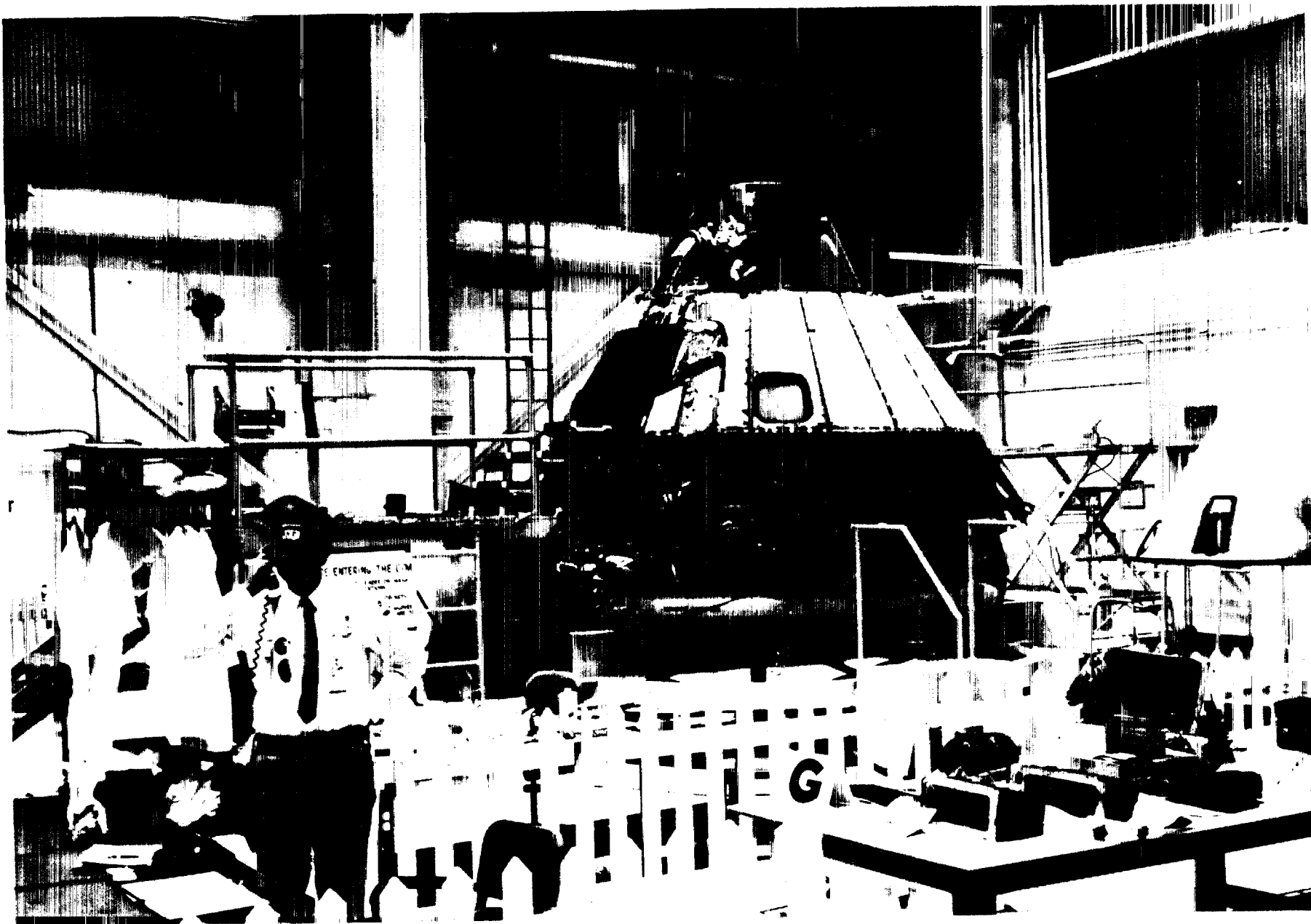
ENCLOSURE V-14  
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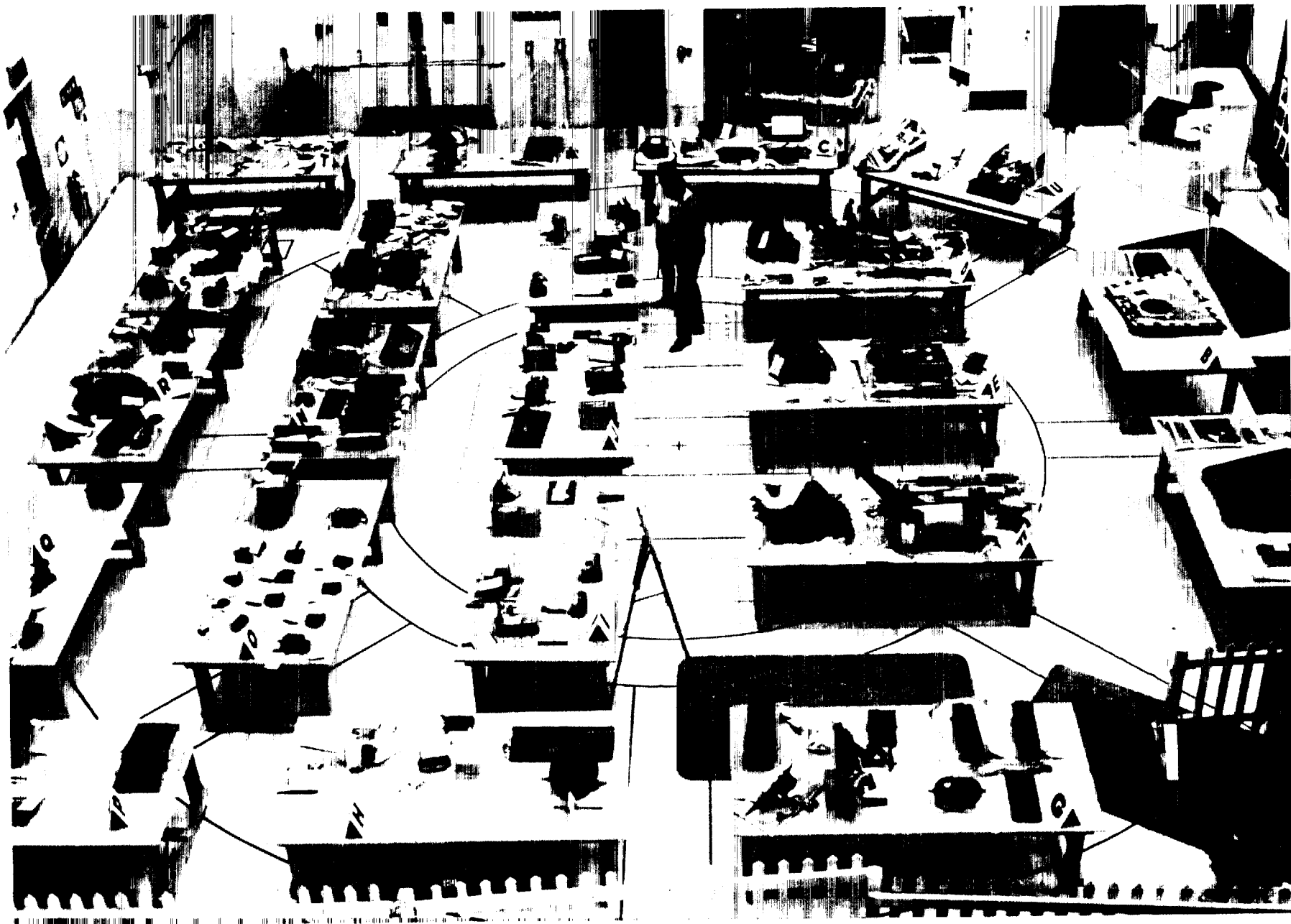
ENCLOSURE V-15

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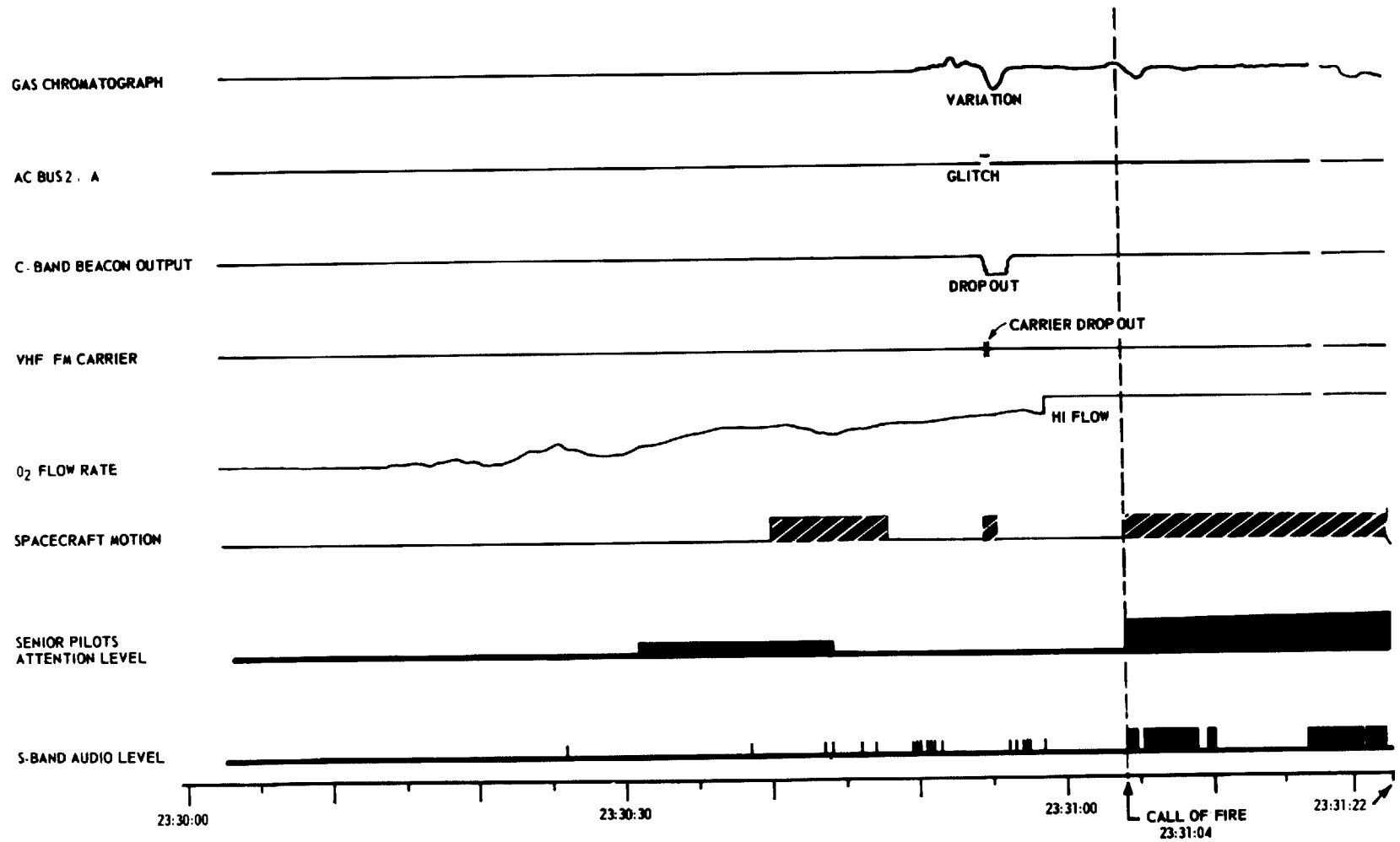
COMMAND MODULE OF SPACECRAFT 012 IN FINAL DISASSEMBLY AT THE  
PYROTECHNICS INSTALLATION BUILDING



PYROTECHNICS INSTALLATION BUILDING BONDED DISPLAY AREA ON MARCH 14, 1967

ENCLOSURE V-16  
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# SUMMARY OF RELEVANT TIME LINE

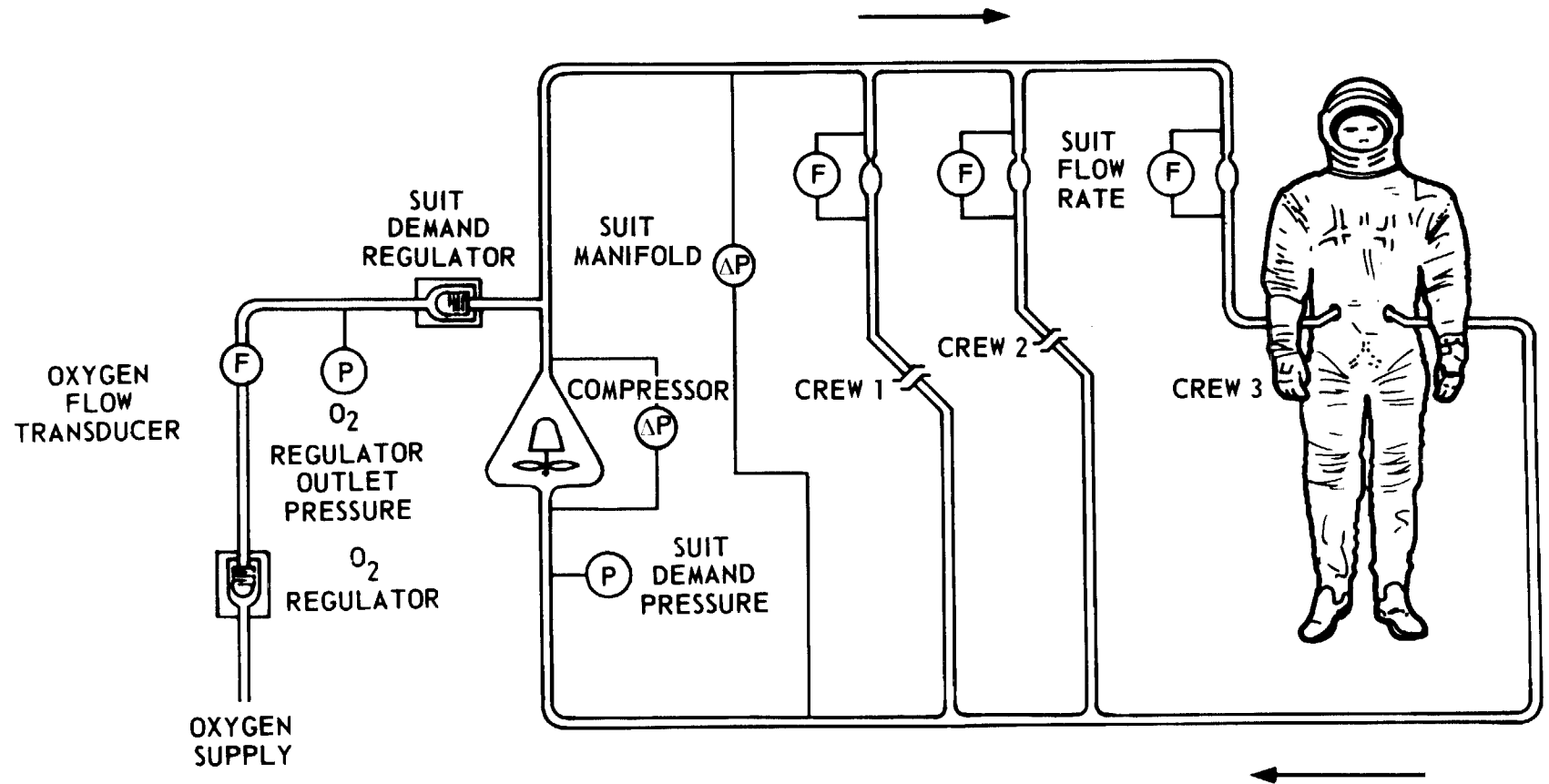


ENCLOSURE V-17

5-47

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# SUIT CIRCUIT SIMPLIFIED SCHEMATIC



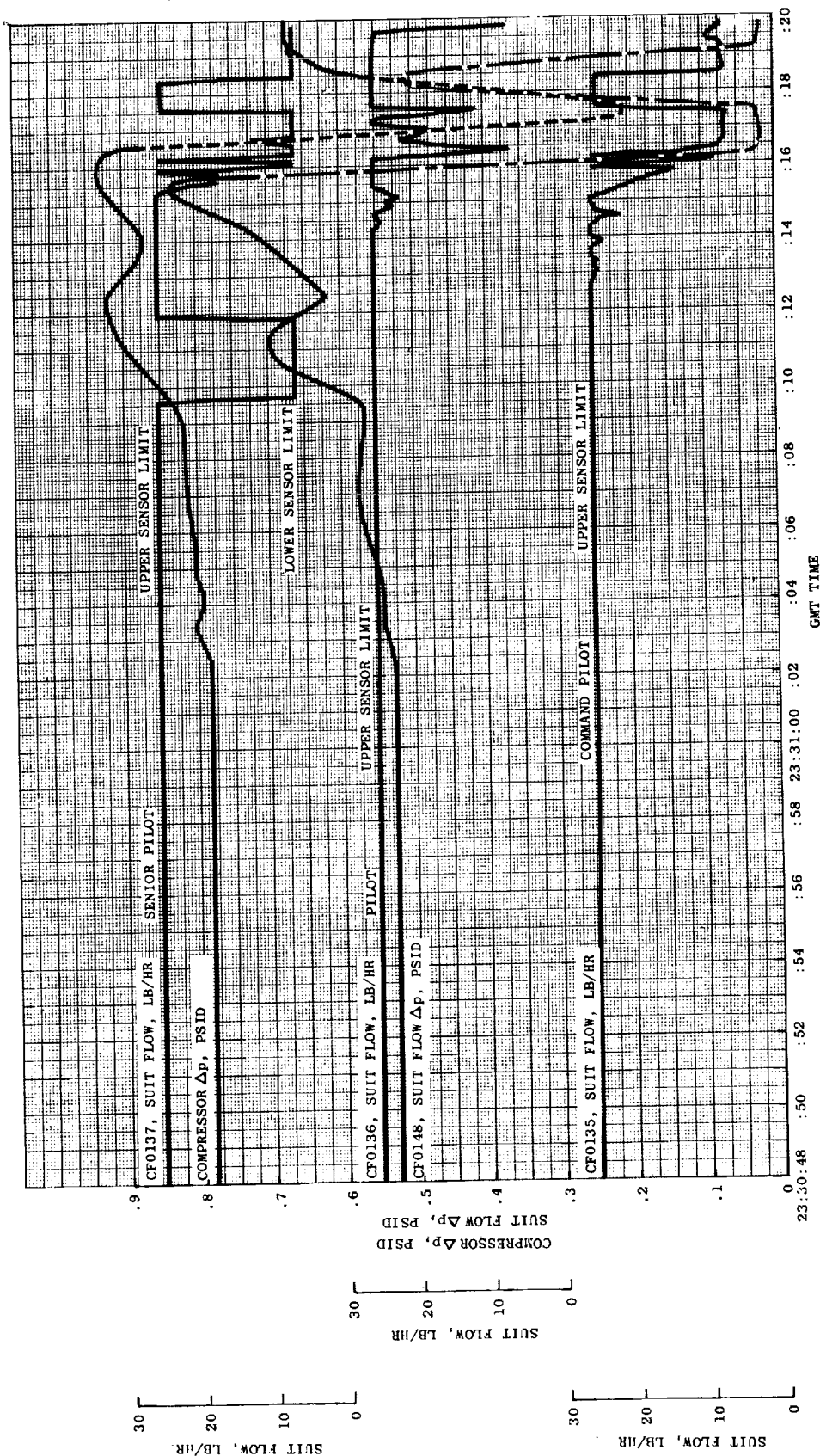
ENCLOSURE V-18

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# SUIT O<sub>2</sub> FLOW RATES



ENCLOSURE V-19

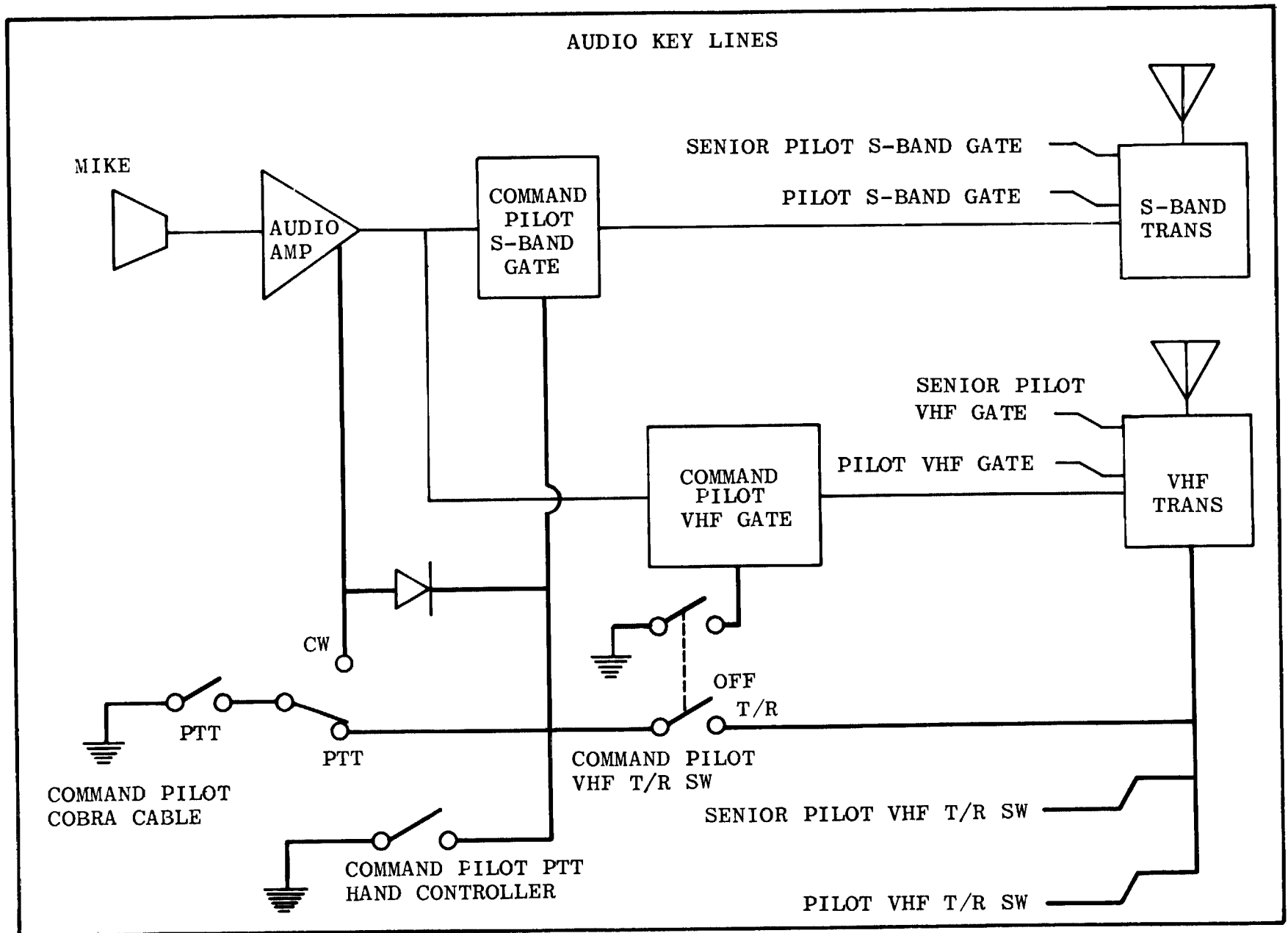
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# AUDIO KEY LINES

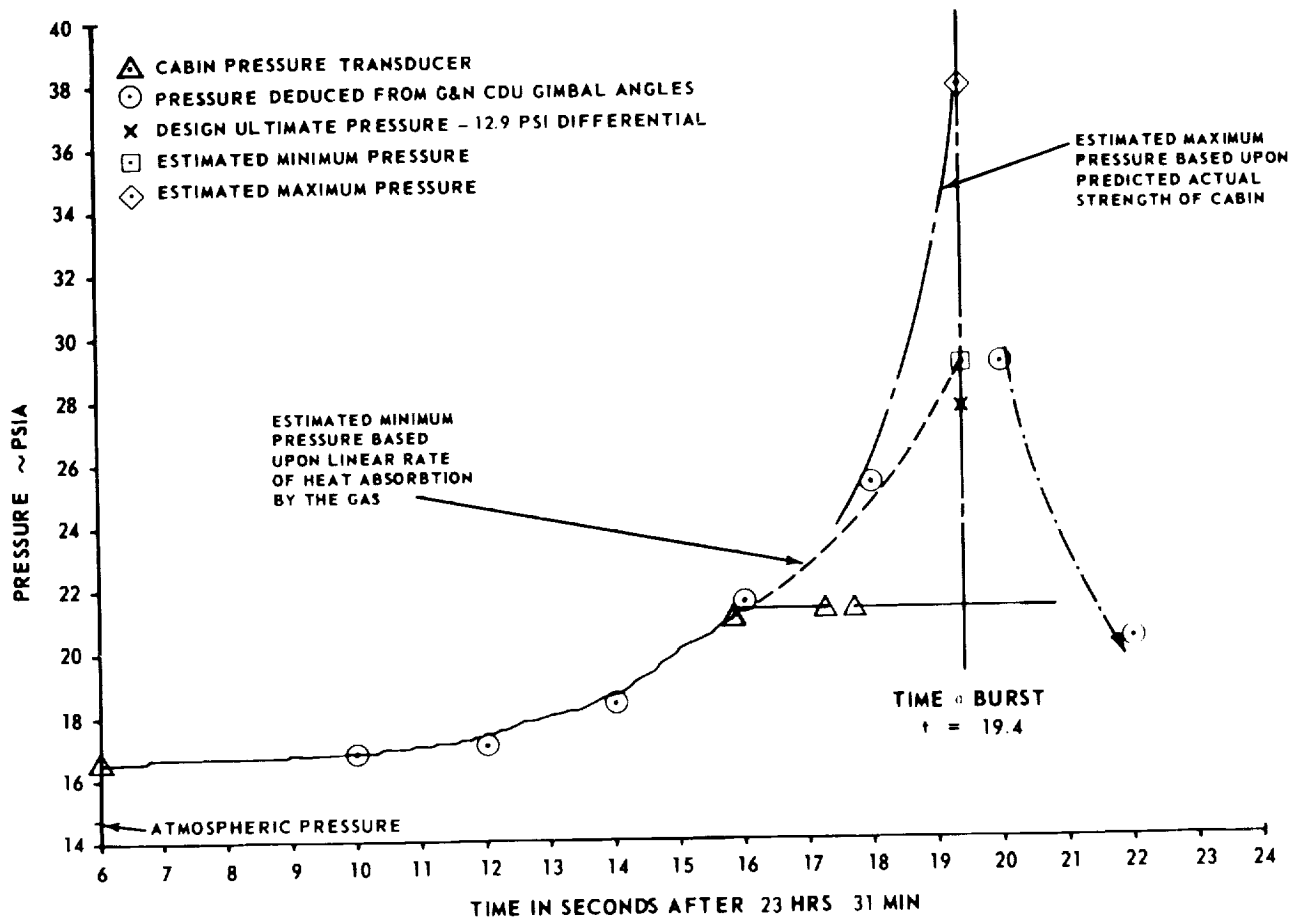


ENCLOSURE V-20

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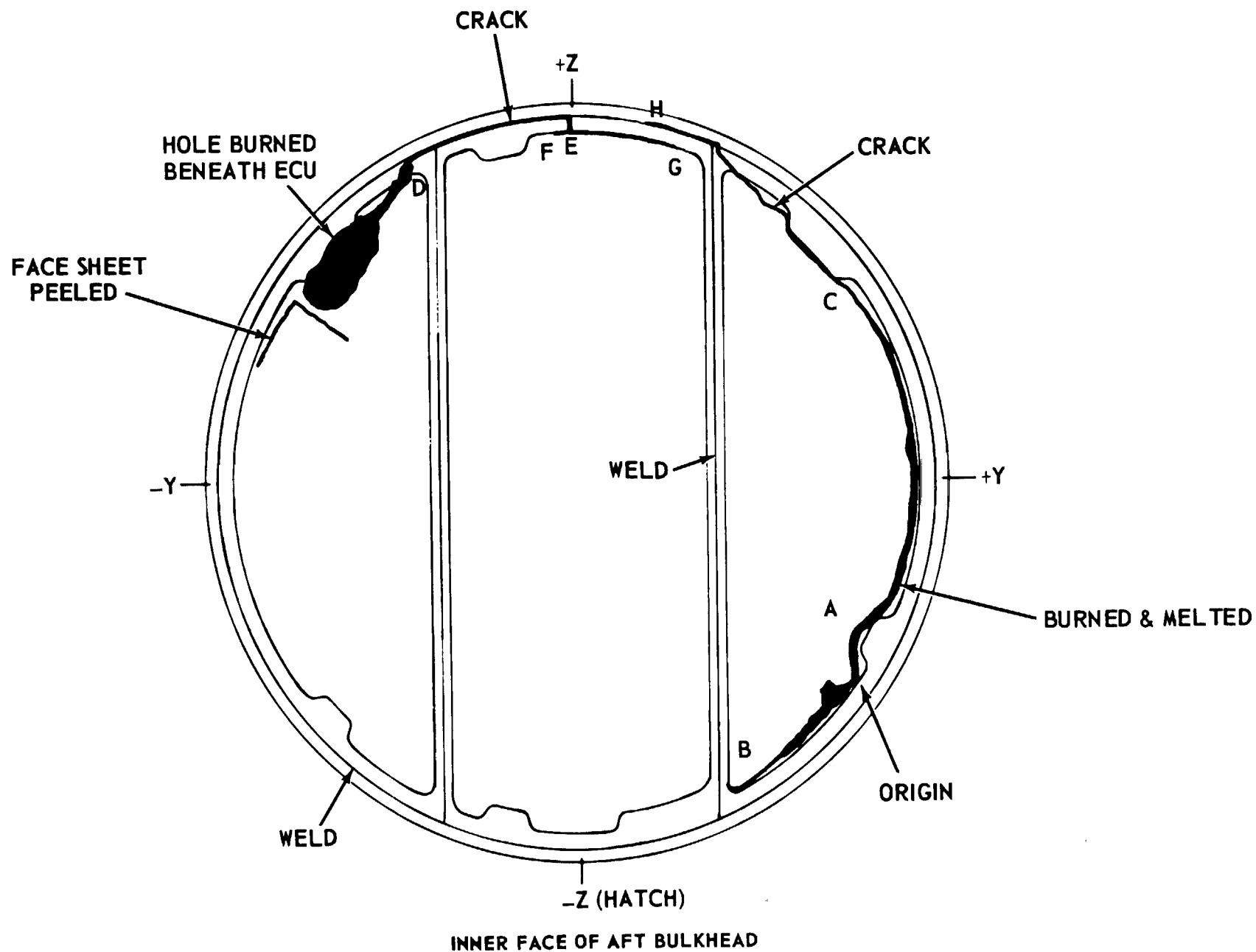


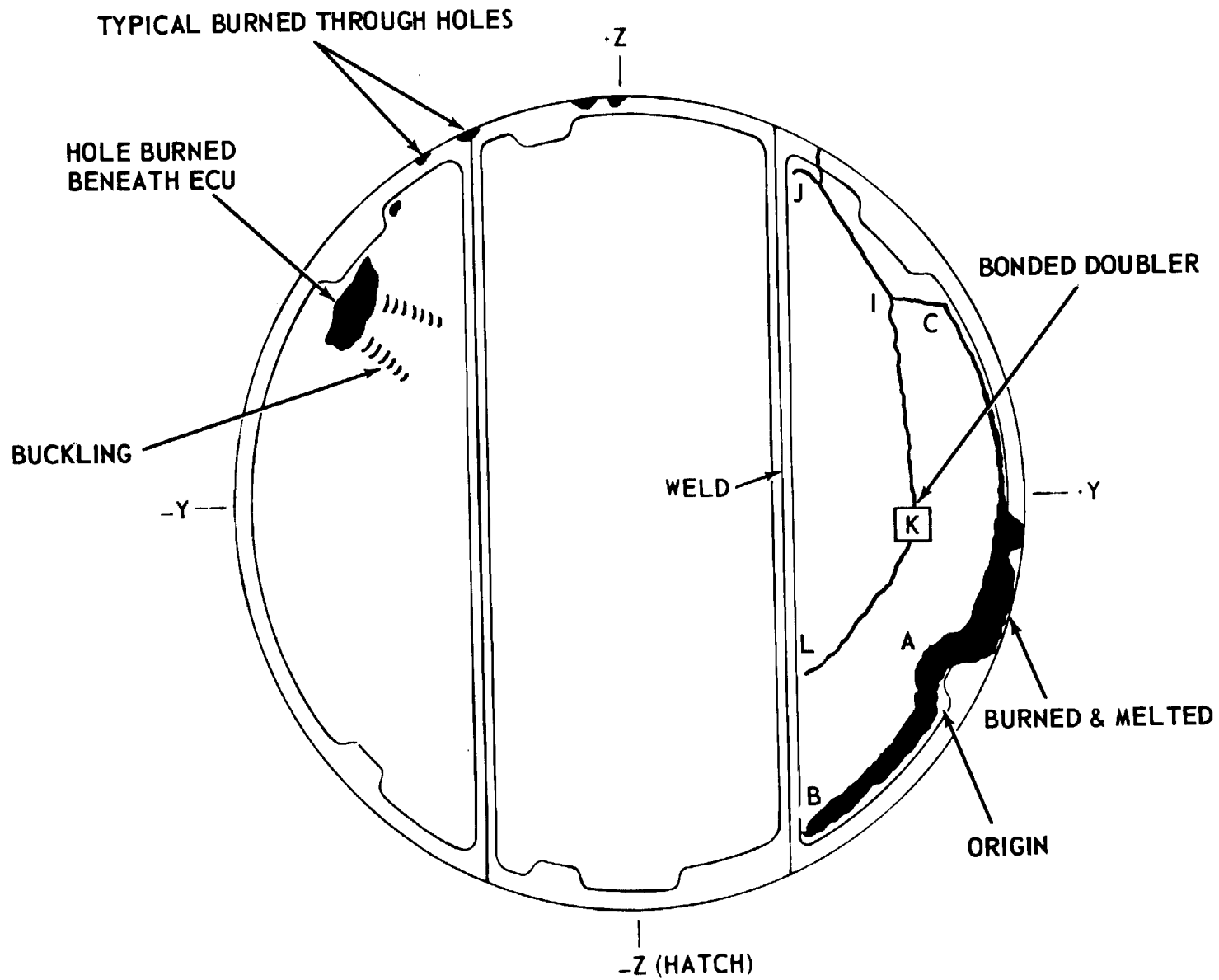
CABIN PRESSURE

ENCLOSURE V-21

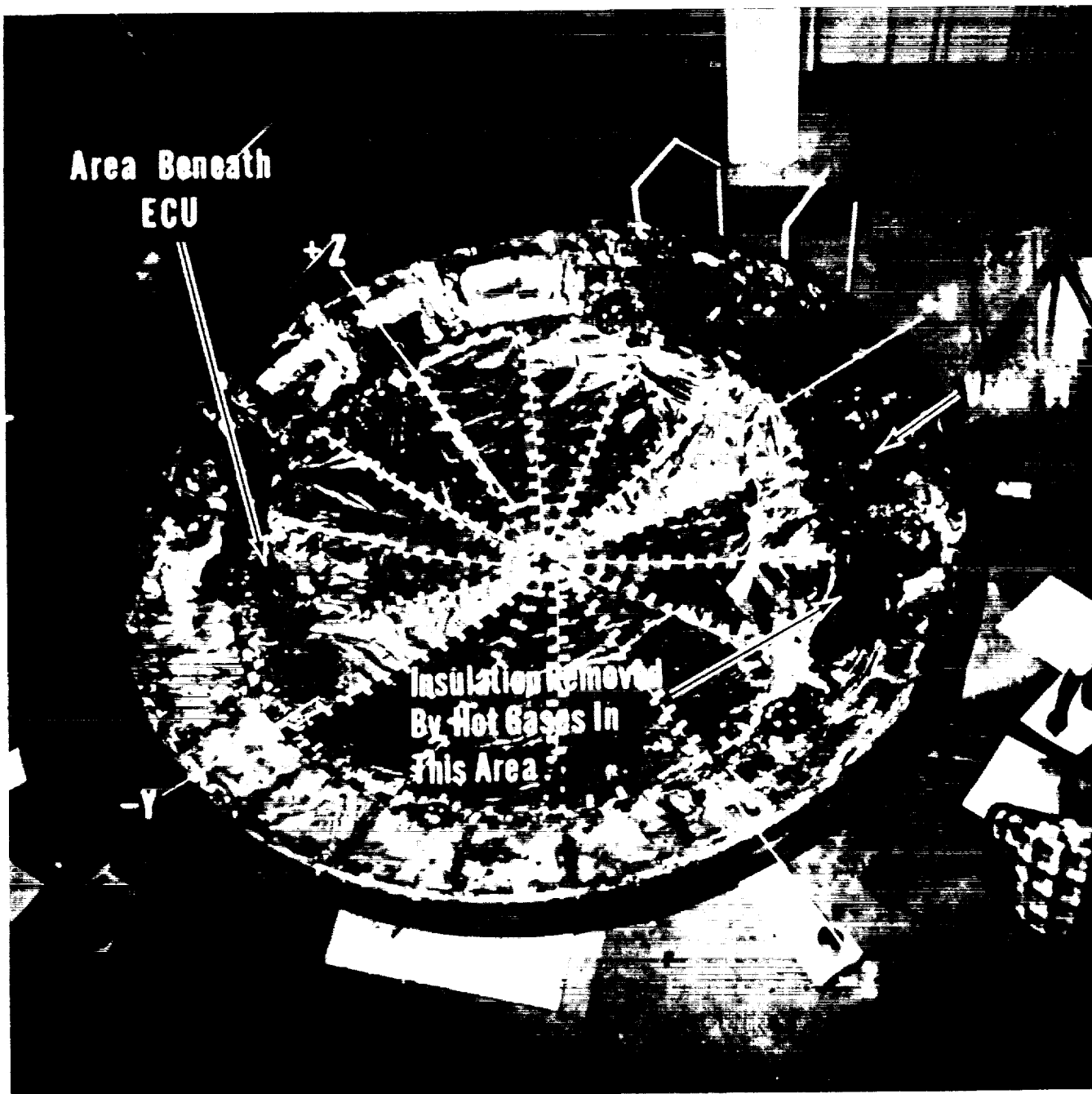
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ENCLOSURE V-22





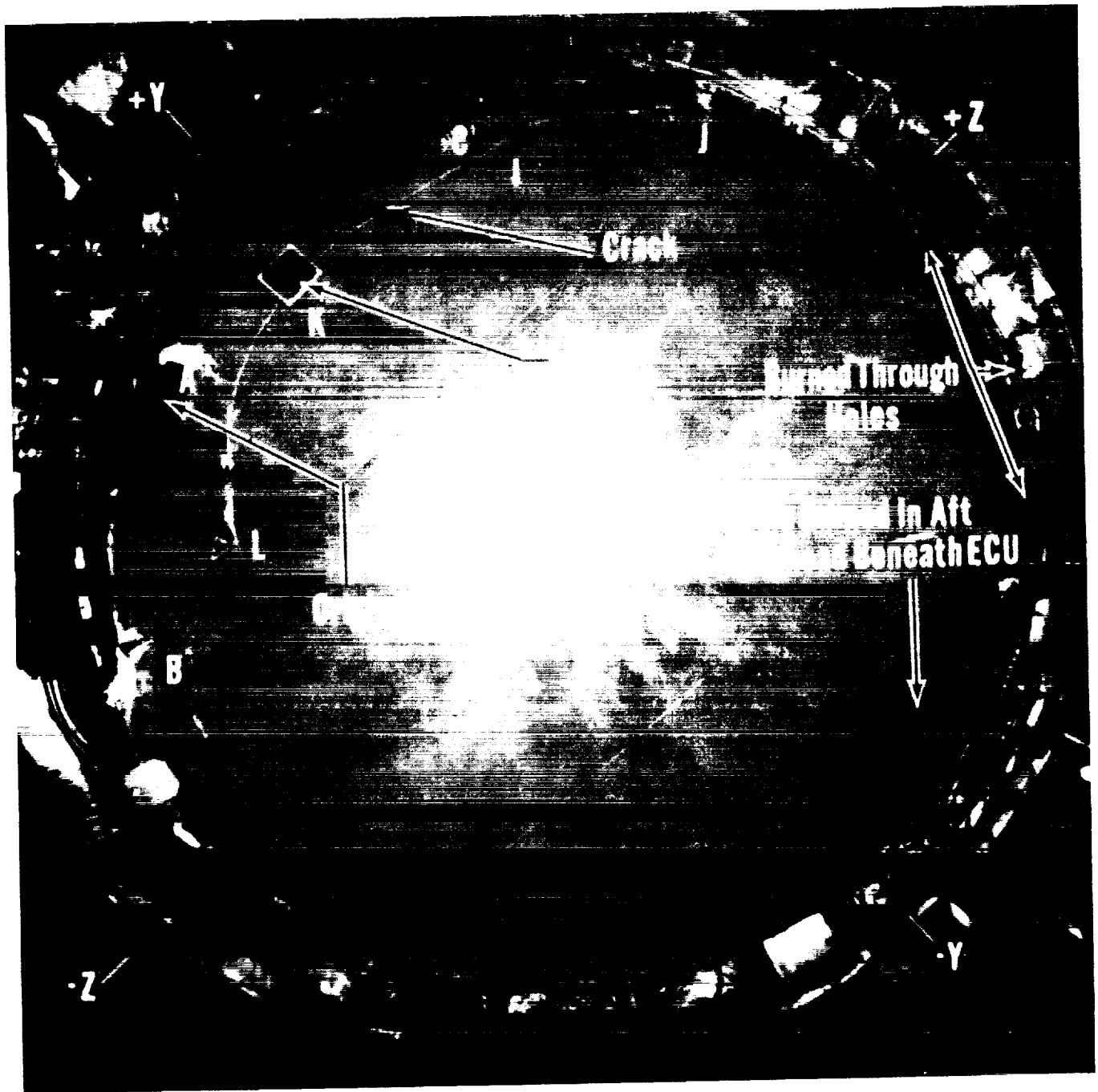
OUTER FACE SHEET OF AFT BULKHEAD



AFT HEATSHIELD DAMAGE

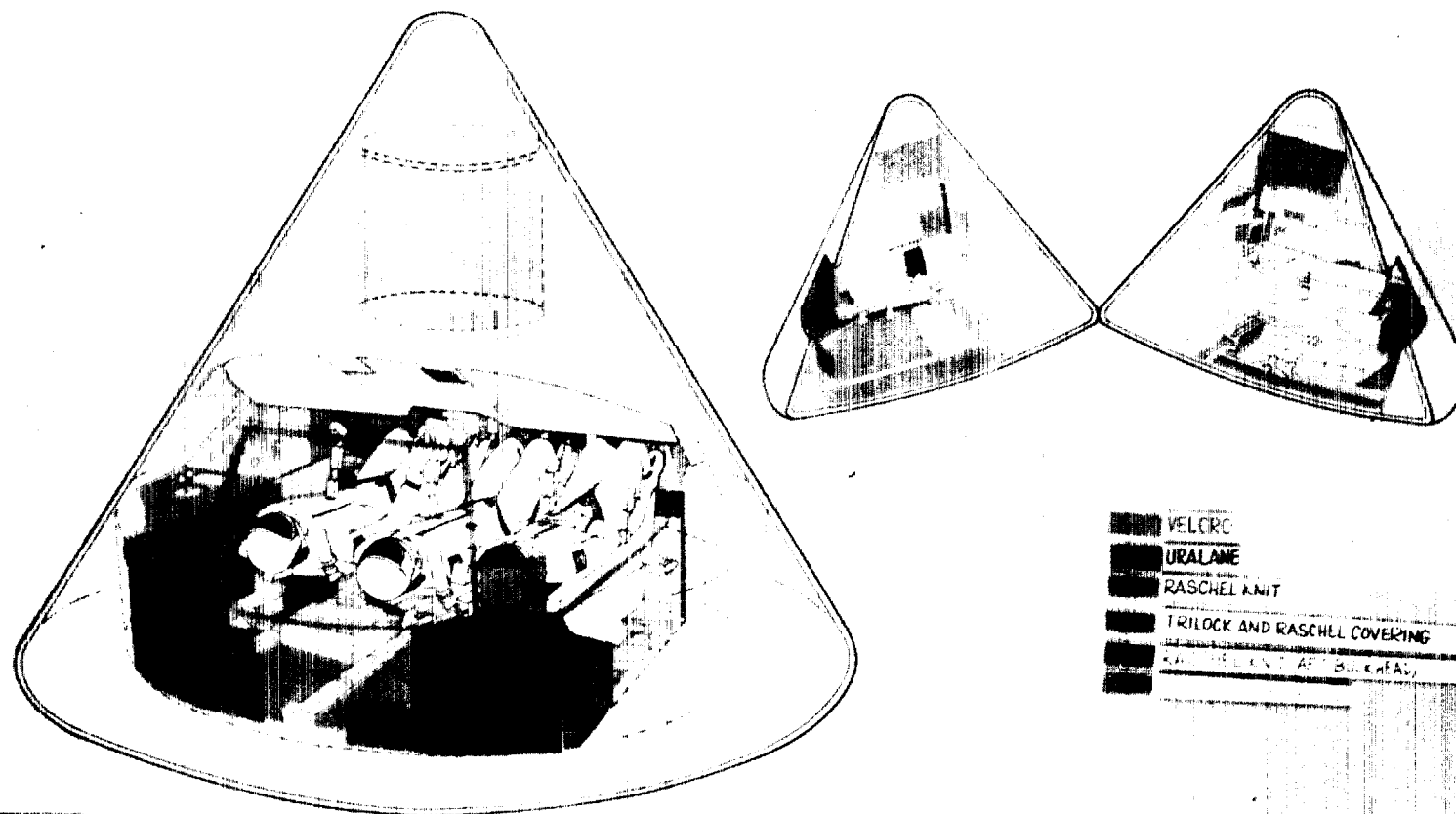
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ENCLOSURE V-24



AFT BULKHEAD OF CREW COMPARTMENT

# EXPOSED NON-METALLIC MATERIALS



	VELCRO
	URALANE
	RASCHEL KNIT
	TRILOCK AND RASCHEL COVERING
	BLACK VELCRO AFT BULKHEAD

2/20/67  
2/20/67  
2/20/67  
2/20/67

EXPOSED NON-METALLIC MATERIALS LOCATION - AFT BULKHEAD ADDED

ENCLOSURE V-26

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BLACK AND WHITE PHOTOGRAPH





WIRING ASSESSMENT

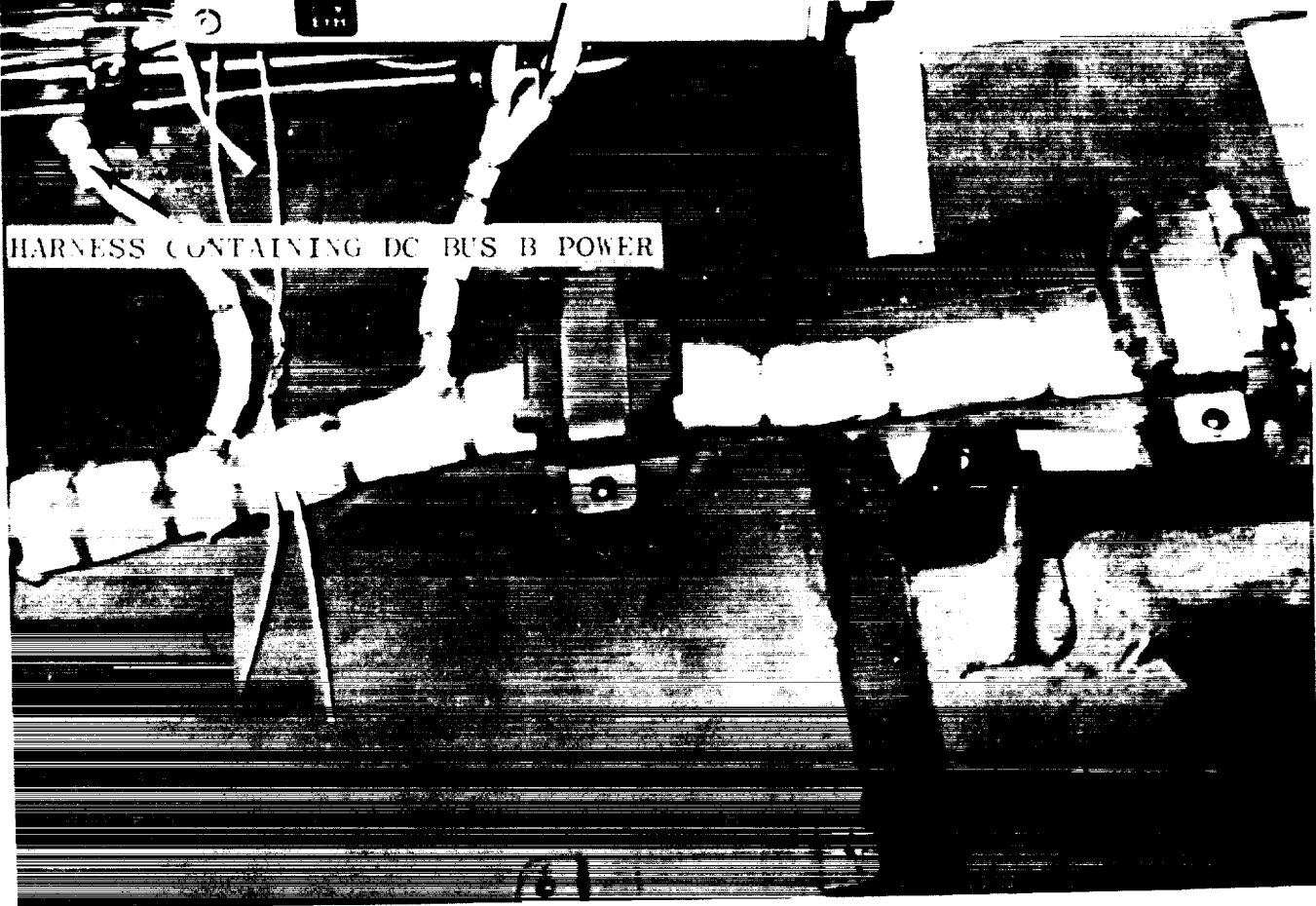


LITHIUM HYDROXIDE ACCESS DOOR



HARNESS CONTAINING DC BUS A AND B POWER

HARNESS CONTAINING DC BUS B POWER



**PART VI**

**FINDINGS, DETERMINATIONS  
AND  
RECOMMENDATIONS**

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## BOARD FINDINGS, DETERMINATIONS AND RECOMMENDATIONS

In this Review, the Board adhered to the principle that reliability of the Command Module and the entire system involved in its operation is a requirement common to both safety and mission success. Once the Command Module has left the earth's environment the occupants are totally dependent upon it for their safety. It follows that protection from fire as a hazard involves much more than quick egress. The latter has merit only during test periods on earth when the Command Module is being readied for its mission and not during the mission itself. The risk of fire must be faced; however, that risk is only one factor pertaining to the reliability of the Command Module that must receive adequate consideration. Design features and operating procedures that are intended to reduce the fire risk must not introduce other serious risks to mission success and safety.

### 1. FINDING:

- a. There was a momentary power failure at 23:30:55 GMT.
- b. Evidence of several arcs was found in the post fire investigation.
- c. No single ignition source of the fire was conclusively identified.

#### DETERMINATION:

The most probable initiator was an electrical arc in the sector between the -Y and +Z spacecraft axes. The exact location best fitting the total available information is near the floor in the lower forward section of the left-hand equipment bay where Environmental Control System (ECS) instrumentation power wiring leads into the area between the Environmental Control Unit (ECU) and the oxygen panel. No evidence was discovered that suggested sabotage.

### 2. FINDING:

- a. The Command Module contained many types and classes of combustible material in areas contiguous to possible ignition sources.
- b. The test was conducted with a 16.7 pounds per square inch absolute, 100 percent oxygen atmosphere.

#### DETERMINATION:

The test conditions were extremely hazardous.

#### RECOMMENDATION:

The amount and location of combustible materials in the Command Module must be severely restricted and controlled.

### 3. FINDING:

- a. The rapid spread of fire caused an increase in pressure and temperature which resulted in rupture of the Command Module and creation of a toxic atmosphere. Death of the crew was from asphyxia due to inhalation of toxic gases due to fire. A contributory cause of death was thermal burns.
- b. Non-uniform distribution of carboxyhemoglobin was found by autopsy.

#### DETERMINATION:

Autopsy data leads to the medical opinion that unconsciousness occurred rapidly and that death followed soon thereafter.

### 4. FINDING:

Due to internal pressure, the Command Module inner hatch could not be opened prior to rupture of the Command Module.

#### DETERMINATION:

The crew was never capable of effecting emergency egress because of the pressurization before rupture and their loss of consciousness soon after rupture.

#### RECOMMENDATION:

The time required for egress of the crew be reduced and the operations necessary for egress be simplified.

### 5. FINDING:

Those organizations responsible for the planning, conduct and safety of this test failed to identify it as being hazardous. Contingency preparations to permit escape or rescue of the crew from an internal Command Module fire were not made.

- a. No procedures for this type of emergency had been established either for the crew or for the spacecraft pad work team.
- b. The emergency equipment located in the White Room and on the spacecraft work levels was not

designed for the smoke condition resulting from a fire of this nature.

c. Emergency fire, rescue and medical teams were not in attendance.

d. Both the spacecraft work levels and the umbilical tower access arm contain features such as steps, sliding doors and sharp turns in the egress paths which hinder emergency operations.

**DETERMINATION:**

Adequate safety precautions were neither established nor observed for this test.

**RECOMMENDATIONS:**

a. Management continually monitor the safety of all test operations and assure the adequacy of emergency procedures.

b. All emergency equipment (breathing apparatus, protective clothing, deluge systems, access arm, etc.) be reviewed for adequacy

c. Personnel training and practice for emergency procedures be given on a regular basis and reviewed prior to the conduct of a hazardous operation.

d. Service structures and umbilical towers be modified to facilitate emergency operations.

**6. FINDING:**

Frequent interruptions and failures had been experienced in the overall communication system during the operations preceding the accident.

**DETERMINATION:**

The overall communication system was unsatisfactory.

**RECOMMENDATIONS:**

a. The Ground Communication System be improved to assure reliable communications between all test elements as soon as possible and before the next manned flight.

b. A detailed design review be conducted on the entire spacecraft communication system.

**7. FINDING:**

a. Revisions to the Operational Checkout Procedure for the test were issued at 5:30 pm EST January 26, 1967 (209 pages) and 10:00 am EST January 27, 1967 (4 pages).

b. Differences existed between the Ground Test Procedures and the In-Flight Check Lists.

**DETERMINATION:**

Neither the revision nor the differences contributed to the accident. The late issuance of the revision, however, prevented test personnel from becoming adequately familiar with the test procedure prior to its use.

**RECOMMENDATIONS:**

a. Test Procedures and Pilot's Checklists that represent the actual Command Module configuration be published in final form and reviewed early enough to permit adequate preparation and participation of all test organization.

b. Timely distribution of test procedures and major changes be made a constraint to the beginning of any test.

**8. FINDING:**

The fire in Command Module 012 was subsequently simulated closely by a test fire in a full-scale mock-up.

**DETERMINATION:**

Full-scale mock-up fire tests can be used to give a realistic appraisal of fire risks in flight-configured spacecraft.

**RECOMMENDATION:**

Full-scale mock-ups in flight configuration be tested to determine the risk of fire.

**9. FINDING:**

The Command Module Environmental Control System design provides a pure oxygen atmosphere.

**DETERMINATION:**

This atmosphere presents severe fire hazards if the amount and location of combustibles in the Command Module are not restricted and controlled.

**RECOMMENDATIONS:**

a. The fire safety of the reconfigured Command Module be established by full-scale mock-up tests.

b. Studies of the use of a diluent gas be continued with particular reference to assessing the problems of gas detection and control and the risk of additional operations that would be required in the use of a two gas atmosphere.

#### 10. FINDING:

Deficiencies existed in Command Module design, workmanship and quality control, such as:

a. Components of the Environmental Control System installed in Command Module 012 had a history of many removals and of technical difficulties including regulator failures, line failures and Environmental Control Unit failures. The design and installation features of the Environmental Control Unit makes removal or repair difficult.

b. Coolant leakage at solder joints has been a chronic problem.

c. The coolant is both corrosive and combustible.

d. Deficiencies in design, manufacture, installation, rework and quality control existed in the electrical wiring.

e. No vibration test was made of a complete flight-configured spacecraft.

f. Spacecraft design and operating procedures currently require the disconnecting of electrical connections while powered.

g. No design features for fire protection were incorporated.

#### DETERMINATION:

These deficiencies created an unnecessarily hazardous condition and their continuation would imperil any future Apollo operations.

#### RECOMMENDATIONS:

a. An in-depth review of all elements, components and assemblies of the Environmental Control System be conducted to assure its functional and structural integrity and to minimize its contribution to fire risk.

b. Present design of soldered joints in plumbing be modified to increase integrity or the joints be replaced with a more structurally reliable configuration.

c. Deleterious effects of coolant leakage and spillage be eliminated.

d. Review of specifications be conducted, 3-dimensional jigs be used in manufacture of wire bundles and rigid inspection at all stages of wiring design, manufacture and installation be enforced.

e. Vibration tests be conducted of a flight-configured spacecraft.

f. The necessity for electrical connections or disconnections with power on within the crew compartment be eliminated.

g. Investigation be made of the most effective means of controlling and extinguishing a spacecraft fire. Auxiliary breathing oxygen and crew protection from smoke and toxic fumes be provided.

#### 11. FINDING:

An examination of operating practices showed the following examples of problem areas:

a. The number of the open items at the time of shipment of the Command Module 012 was not known. There were 113 significant Engineering Orders not accomplished at the time Command Module 012 was delivered to NASA; 623 Engineering Orders were released subsequent to delivery. Of these, 22 were recent releases which were not recorded in configuration records at the time of the accident.

b. Established requirements were not followed with regard to the pre-test constraints list. The list was not completed and signed by designated contractor and NASA personnel prior to the test, even though oral agreement to proceed was reached.

c. Formulation of and changes to pre-launch test requirements for the Apollo spacecraft program were unresponsive to changing conditions.

d. Non-certified equipment items were installed in the Command Module at time of test.

e. Discrepancies existed between NAA and NASA MSC specifications regarding inclusion and positioning of flammable materials.

f. The test specification was released in August 1966 and was not updated to include accumulated changes from release date to date of the test.

#### DETERMINATION:

Problems of program management and relationships between Centers and with the contractor have led in some cases to insufficient response to changing program requirements.

#### RECOMMENDATION:

Every effort must be made to insure the maximum clarification and understanding of the responsibilities of all the organizations involved, the objective being a fully coordinated and efficient program.

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